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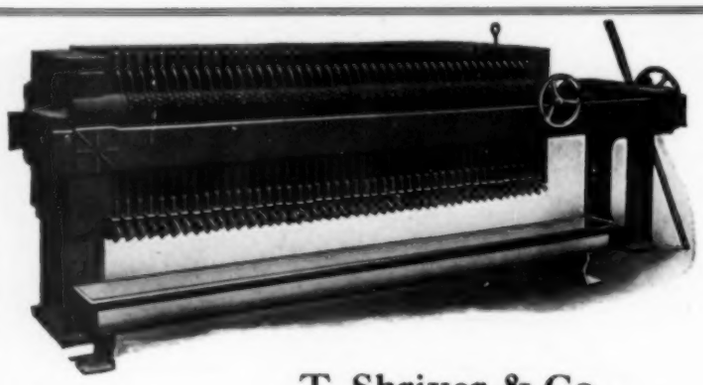

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Metallurgical and Chemical Engineering

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"Fair Protection" for the American Chemical Manufacturer

The two papers by Mr. I. F. Stone and Mr. Maximilian Toch presented before the New York Section of the American Chemical Society last week and reported on page 710 of this issue, are more than mere papers. They are human documents of a most lively and important episode in the history of the American chemical industries. The quiet unassuming way of the authors typifies the quiet, unassuming way in which, since the beginning of the European war, the American chemist has gone ahead and has done things. Mr. Stone's paper is a record of a long string of big achievements. Mr. Toch's paper is the story of the creation of the new American barium industry.

As was said at this place last month, part of the present enormous activity in the chemical industries will stop when the war stops, since it has to do with war materials, but by far the most of the present activity will be lasting for the benefit of the whole country, if the American nation is willing that it be so. What is it that the chemical industry has a right to expect from the American nation? Nothing more nor less than a fair attitude of mind of the American nation toward the American chemical industry: a fair appreciation of its accomplishments and its aim, a fair recognition of the fact that chemical brains need capital for realization of their ideas and that capital needs fair protection. It seems right to discuss now more in detail what such "fair protection" would consist of.

In the first place, protection must be procured against unfair practices on the part of foreign competitors. But how shall such "unfair practices" be defined? The principal point is that when the war is over there will be great danger that the newly created chemical industries in this country be quickly destroyed by dumping on the markets of this country foreign products at a price below the selling price of the products in the producers' home markets. The American chemical industry has a right to expect from the nation's law makers that such methods of destroying dangerous competitors as are considered unfair and are now forbidden by law to Americans in the United States, should also be considered unfair and forbidden by law to importers from other countries. That is, the American chemical industry has a right to expect the enactment of an anti-dumping clause.

But whoever reads carefully Mr. Stone's and Mr. Toch's papers in this issue, or Mr. Stone's elaborate paper on the aniline dye situation in our issue of Oct. 1 (page 663) or Dr. Herty's opening address at the Exposition of Chemical Industries in the same issue

(page 695), or who endeavors to get exact knowledge concerning the situation from anybody who has a first-hand knowledge of the facts, will recognize that the enactment of an anti-dumping clause is not all that is needed. Tariff reform must be fairly and squarely considered. There are two main points which fairness requires in such consideration.

In the first place it must be strictly kept in mind that the American chemical industries face "a condition, not a theory." The abstract question of the desirability or undesirability of protective tariffs has been and will continue to be a fit subject of extended discussions by political economists, but it has nothing to do with the special concrete situation with which the chemical industries of this country and all who depend in some way on the products of the chemical industries are now confronted. The situation is such that academic discussions are almost out of place. But it may be said in parenthesis that if in these days any American chemist has an idle moment, he can find a great deal to satisfy his sense of humor in reading over the volumes of political economy which have been written on the theory of protective tariffs and contrasting the theory with the facts of the present moment. Just one example will explain what we mean. Chapters and chapters have been written on the question: Should industrial entities correspond to political entities? As a general academic question it is highly debatable. But it will be hard to find any sensible person of whatever party affiliations who has not learned from the experience of the past year the lesson that it is all important for the future of the American nation to be industrially self-contained. As Dr. Herty expressed it in his admirable presidential address before the American Chemical Society in Seattle, "in these days of rapidly shifting international relations the only sound and rational policy is national self-containedness." Likewise the old argument that a protective tariff, being a restraint, cannot have any positive virtue and cannot create industries, has absolutely no application to the present situation. The chemical industries which this country needed have been created during the past year by the pluck of the American chemist backed by American capital. Shall they be permitted to grow until they are firmly and permanently established? And what is necessary to accomplish this end?

This is the only real question. But to find the right answer, it is all important—and this is the second point to be kept in mind—that the whole consideration of the matter be taken out of party politics. The most promising and a decidedly practical way of accomplishing this was outlined by Mr. Howard H. Gross, president of the Tariff Commission League, in two addresses before the National Exposition of Chemical Industries in New York last month. As reported in our last issue (page 676), Mr. Gross argued that the net result of thirty years of "tariff tinkering" has been that nobody is satisfied, that business has been periodically upset, that hundreds of millions of money have been lost and millions of workers distressed. What is needed now is a really strong permanent non-partisan tariff commission of the highest personnel with long tenure of office, to make impartial investigations and recommend to Congress needed tariff adjustments on scientific principles. Whatever may be done in general, the conditions of the chemical industries require that something be done for their protection and that something be done very soon.

Shall the present vigorous growth of the American chemical industry remain but an episode in its history or shall it be the beginning of a new era? The American chemist has done his part faithfully and vigorously. It is for the American nation, as represented by Congress, to do the rest.

Non-Ferrous Metals During the War

Wide fluctuations in the price of a metal are usually ascribed to speculation, but the course of metal prices since the opening of the European war, although showing wide fluctuations, is not to be attributed to speculative influences. There is rather a dislocation of the ordinary movement of material whereby it becomes difficult to forecast the relation between supply and demand, while it is probably also the case that there have been important changes in the employment of metals for various war purposes, which have effected quick changes in the relation between supply and demand.

The non-ferrous metal markets certainly have pursued no orderly course in the fourteen months that have elapsed since the war opened. The first movement attributed to the war was a violent advance in tin, resulting in a doubling in the price before the war was a fortnight old. There was a veritable scare, due to the possibility that it would be found impossible to move tin from the Far East. A similar advance occurred in antimony, which advanced to three prices. Spelter, on the other hand, advanced because it was reported that large tonnages would be exported to England. The advances were practically all lost by the middle of September. Later there began a more orderly but still quite irregular advance in nearly all the metals. Lead, traditionally associated with war, was conspicuous by its failure to advance, though eventually it did advance in moderate fashion.

That there have been changes in the technique of war material manufacture is suggested by some of the market fluctuations. Spelter, which early rose and fell, and then toward the close of the old year began a definite and important rise, reached a very high point early in June, at more than five times its price of before the war, and since then it has been declining until lately it has sold at less than three prices. Aluminium, on the other hand, did not begin any sharp advance until last May, and the advance did not become sensational until September, about three months after spelter had started its sharp decline. Early this month it crossed the 50-cent line, truly a remarkable performance. The divergent movement between spelter and aluminium can hardly be ascribed entirely to manipulation or to a misjudging of market prospects by either buyers or sellers.

Regular consumers of the non-ferrous metals, entirely unaccustomed to such violent fluctuations as have char-

acterized the markets during the war, have not only been greatly inconvenienced but in many cases have suffered very severe losses. In many cases, probably, trade has been permanently lost. Unable to secure supplies of given materials at former prices, consumers of many products have been driven to the use of substitutes, and the substitute may in many cases find permanent employment.

The sheet-galvanizing industry has not yet been able to determine whether it has permanently or only temporarily lost a large proportion of its trade. It is estimated that since early in the year, when the advance in spelter forced the mills to ask much higher prices for galvanized sheets, the demand has ranged from 20 to 35 per cent of normal, the normal demand being nearly a million net tons a year. To an extent the consumptive requirements have been met by stocks in the hands of jobbers and manufacturing consumers, but there has doubtless been substitution in many instances, and whether the galvanized-sheet trade will ever regain its former proportions remains a matter of doubt. Prices lately asked by the mills for galvanized sheets are not considered sufficiently high to curtail consumption to any great extent, provided they were steadily maintained, but buyers are chary of purchasing, fearing sharp declines at any moment.

Iron Industry Making New Records

In the last two months of 1914 the iron and steel industry was in a state of unparalleled depression. The production of steel, in proportion to available capacity, was the smallest on record. Pig iron prices were lower than at any time in ten years, and steel prices lower than at any time in fifteen years. For November and December the United States Steel Corporation reported the lowest monthly earnings in its history, earnings at the rate of only $32,000,000 a year.

Never has the iron industry experienced so complete a change as that which has occurred since then, in approximately ten months. The production of both pig iron and steel ingots is now at a new high record rate, and there has been a continued and very important advance in steel prices, while in the past four months there has been a moderate improvement in pig iron prices. In all the past there can be found no precise parallel to this general movement. In 1908 production reached a relatively low rate, but prices did not decline correspondingly. In 1905, in 1909, and in 1912 there were sharp upward movements in prices, corresponding in general to the rate of the past ten months, but there was not a corresponding increase in tonnage outputs, as the percentage of idleness at the beginning of these various movements was not as great as was that at the beginning of this movement. Passing back to 1899 one finds more rapid price advances, spectacular as compared with those of recent months, but these occurred through demand having developed, in a period of low prices, to such an extent as to engage almost the full capacity of the industry. The price boom of 1899 followed two years each of which in its turn had broken all previous records in the production of pig iron and steel ingots, whereas the pig iron output in the second half of 1914 was less than two-thirds the record output for a half year.

In August certainly, and possibly in July, the steel works attained a new record rate in the production of ingots, and in September the country reached a new record rate in the production of pig iron, the new record pace in pig iron developing later than the new record in steel because the iron foundry trade is not busy and the production of steel-making pig iron had to proceed far enough to absorb the slack thereby produced.

Lake Superior iron ore shipments in August were heavier than in any previous August, and September in turn made a new record for that month, prospects being that the season's shipments will fall very close to the previous record, despite the slow movement early in the present season.

The current production of pig iron is at the rate of fully 36,000,000 tons a year, the best rate previously attained having been 34,000,000 tons a year, in February, 1913, while the greatest production in a calendar year was 30,966,152 tons, in 1913, while the highest production in two successive half years was 32,143,265 tons, in the twelvemonth ended June 30, 1913.

The current production of steel ingots, while it cannot be estimated closely, is known to be at a much greater rate, in proportion to pig-iron production, than has ever obtained before. While pig-iron production is easily at record rate, the consumption of pig iron in iron foundries is distinctly below rates that have obtained in several periods in the past, while in addition to this the output of steel ingots is particularly large in proportion to the pig iron charged. This condition arises in turn from two influences. There is a larger proportion of open-hearth capacity, in proportion to Bessemer, than ever before, and some of the open-hearth works are charging unusually large proportions of scrap as they are working largely upon war orders requiring altogether exceptionally great discards from the ingot. The pressure for steel is such that it is remarked the minutes, even the seconds, are counted against the open-hearth heat, and any practice that conduces to shortening the time is followed.

In striking contrast with the pressure for steel, as steel, is the relatively light operation of many of the finishing mills. There is always, of course, an excess of steel finishing over steel making capacity, and there is the further item that at the present time an altogether abnormal tonnage of forging steel is being produced. In ordinary years about half a million tons of forging billets are produced, but the rate of production at the present time is several times that amount.

The remarkable demand for steel is caused largely, of course, by the war, though the regular domestic demand is fairly good. The war is distinctly responsible for the fact that the change in conditions in ten months is so altogether unprecedented, for it was the war that caused the acute stagnation that characterized the closing months of last year, so that it has emphasized the contrast in each direction.

The Naval Consulting Board's First Meeting and First Recommendation

The Naval Consulting Board was created by Secretary Daniels, but eleven national engineering societies share with him the responsibility for its personnel. Its members, men of highest standing in the professions, serve without remuneration. At the first meeting held in Washington, D. C., on October 6 and 7, the Board organized and decided that the name should be the Naval Consulting Board, not Advisory Board. This is significant. The first recommendation of the Board is that of a large Research Laboratory for the Navy. This plan is in line with the present world-wide recognition of the value of scientific research not merely for the upbuilding of industries, but for the very independence of a nation. The Board is to meet every two months.

THE first meeting of the Naval Consulting Board was held in Washington, D. C., on Oct. 6 and 7, and was concerned largely with matters of organization, though one very important recommendation was made—that of the creation of a large research laboratory for the U. S. Navy.

The board was created by Secretary Daniels of the Navy, who appointed Mr. Thomas A. Edison chairman of the board, but left the selection of the 22 other members of the board to eleven national engineering societies. These eleven societies and their 22 representatives on the board are as follows:

American Institute of Electrical Engineers—
Frank Julian Sprague and Benjamin G. Lamme.
American Institute of Mining Engineers—
William L. Saunders and Benjamin B. Thayer.
American Society of Mechanical Engineers—
William LeRoy Emmet and Spencer Miller.
American Society of Civil Engineers—
Andrew M. Hunt and Alfred Craven.
American Chemical Society—
W. R. Whitney and L. H. Baekeland.
American Electrochemical Society—
Joseph W. Richards and Lawrence Addicks.
Inventors' Guild—
Peter Cooper Hewitt and Thomas Robins.
American Society of Aeronautic Engineers—
Henry A. W. Wood and Elmer A. Sperry.
American Society of Automobile Engineers—
Howard F. Coffin and Andrew L. Riker.
American Aeronautical Society—
Mathew B. Sellers and Hudson Maxim.
American Mathematical Society—
Robert S. Woodward and Arthur G. Webster.

The Board elected the following officers on Oct. 7:
Chairman, Thomas A. Edison.
First Vice-Chairman, Peter Cooper Hewitt.
Second (Acting) Vice-Chairman, W. L. Saunders.
Secretary, Thomas Robins.

Mr. Saunders was the acting chairman at the sessions of the Board which were attended by members of the Board only, with the exception of Mr. M. R. Hutchinson, who was present as Mr. Edison's "ear" and private assistant. Secretary Daniels conferred with the members repeatedly.

It was decided that the name, originally suggested as Naval Advisory Board, should be changed to Naval Consulting Board..

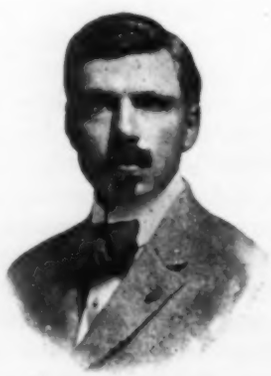
President Wilson received the Board on Oct. 6 at the White House and made the following address:

"There is very little that I can say to you, except to give you a very cordial welcome and to express my very great pleasure in this association of laymen with the Government. But I do want to say this:

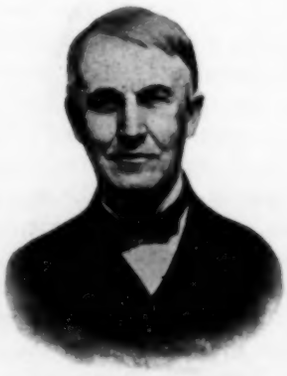
"I think the whole nation is convinced that we ought to be prepared, not for war, but for defense, and very adequately prepared, and that the preparation for defense is not merely a technical matter, that it is not a matter that the Army and Navy alone can take care of, but a matter in which we must have the co-operation of the best brains and knowledge of the country, outside the official service of the Government, as well as inside.

"For my part, I feel that it is only in the spirit of a true democracy that we get together to lend such voluntary aid, the sort of aid that comes from interest, from a knowledge of the varied circumstances that are involved in handling a nation.

"I want you to feel, those of you who are coming to

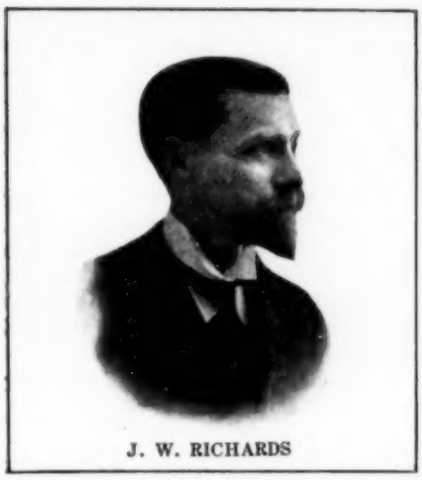


LAWRENCE ADDICKS



THOMAS A. EDISON

LEO H. BAEKELAND



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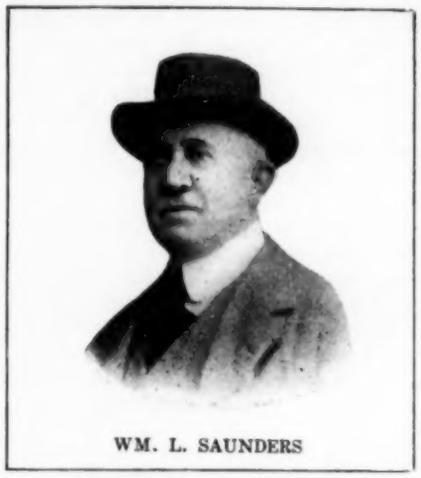

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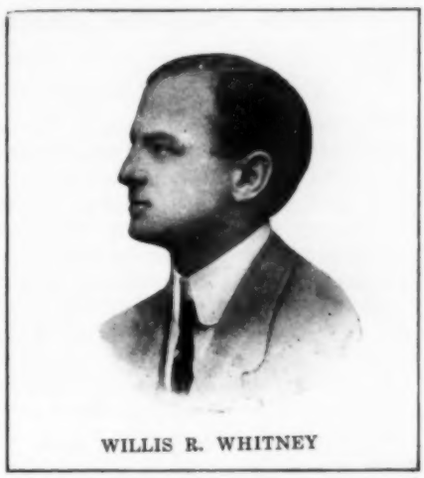


WILLIS R. WHITNEY

the assistance of the professional officers of the Government, that we have a very serious purpose, that we have not asked you to associate yourself with us except for a very definite and practical purpose—to get you to give us your best independent thoughts as to how we ought to make ready for any duty that may fall upon the nation.

"I do not have to expound it to you; you know as well as I do the spirit of America. The spirit of America is one of peace, but one of independence. It is a spirit that is profoundly concerned with peace, because it can express itself best only in peace. It is the spirit of peace and good-will and of human freedom; but it is also the spirit of a nation that is self-conscious, that knows and loves its mission in the world and that knows that it must command the respect of the world.

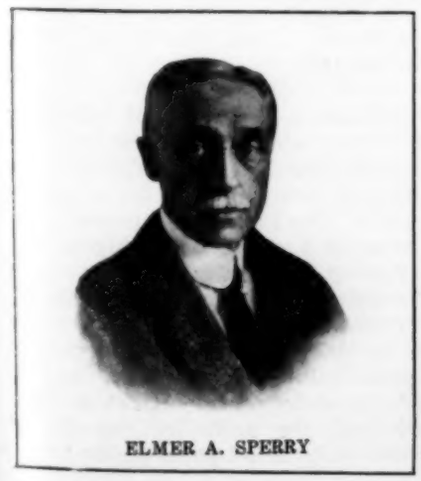
"So it seems to me that we are not working as those who would change anything of America, but only as those who would safeguard everything in America. I know that you will enter into conference with the officers of the Navy in that spirit and with that feeling, and it makes me proud, gentlemen, that the busy men of America—the men who stand at the front of their professions—should be willing in this way to associate themselves voluntarily with the Government in the task in which it needs all sorts of expert and serious advice.

"Nothing ought to be done in this by any single group of persons; everything ought to be done by all of us, united together, and I welcome this association in the most serious and grateful spirit."

It is interesting to reflect that in creating a Naval Consulting Board of scientists and engineers, Secretary Daniels had a predecessor in Napoleon (see Dr. Boekeland's paper in our last issue, page 677). But there is this big difference that as expressed in President Wilson's address the object of the Naval Consulting Board is to help in preparedness for defence, not for aggression. There is another difference in the democratic make-up of the Board in that eleven national engineering societies share with Secretary Daniels the responsibility for the personnel of the Board. The Board is made up of men who stand so high in their professions that they would accept no remuneration for serving their country.

By changing the name from Naval Advisory Board to Naval Consulting Board, the members have made it clear that they do not intend to force their advice unasked upon the Naval Board proper, but that they stand ready to place all their knowledge at the disposal of the Navy in consultation. This move has resulted in very cordial personal relations between civilians and navy men.

The first official recommendation of the Board has been the creation of a Naval Research Laboratory on such a scale that the first investment would be $5,000,000 and the annual operating expenses between $2,500,000 and $3,000,000. We are sure to interpret this recommendation correctly by saying that it is directly in line with the present world-wide recognition of the fact that scientific research on the largest scale is not merely the basis of the creation and evolution of industries, but is indispensable for national self-containedness and the very independence of nations. Germany has understood this truth for many years; Great Britain recognizes it now. The recommendation of the Board means that the United States should have a Naval Research Laboratory commensurate to the national importance of the U. S. Navy.



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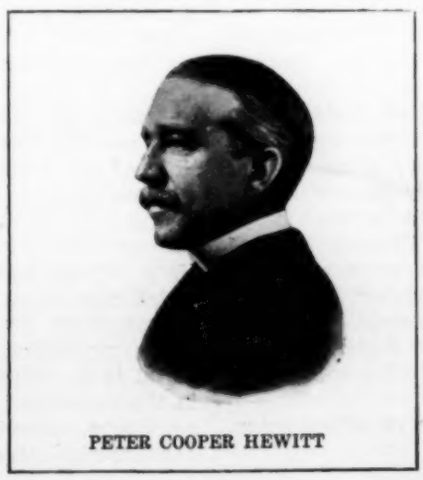
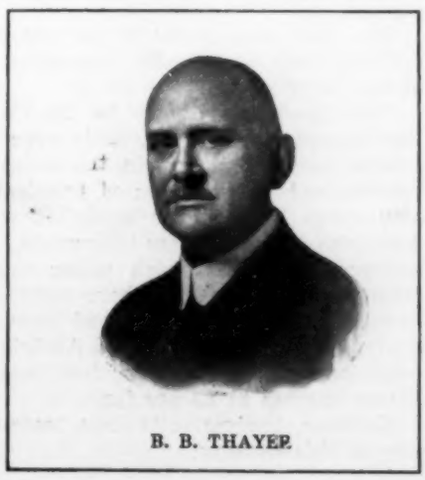


PETER COOPER HEWITT



B. B. THAYER

News from the Chemical Field

The Status of the American Chemical Industry and the New American Barium Industry

The first regular meeting of the session 1915-16 of the New York Section of the American Chemical Society (Dr. T. B. Wagner, chairman) was held on the evening of Oct. 8 in Rumford Hall, Chemists' Building. Two papers were presented which were exceedingly interesting by the manner in which they illustrated the enormous present activity in the chemical field.

Mr. I. F. STONE reviewed **"The Status of the Chemical Industries in the United States at the End of 1915."**

The production of *benzol* has become well established and benzol has become a serious competitor of gasoline as automobile fuel. About 100,000,000 gal. of gasoline are consumed by automobiles per year. Benzol has been carefully tested for automobile service and has been found to have 25 per cent more motive power than gasoline. The price has come down almost to that of gasoline, whereas before the war it was selling for two and three times that of gasoline.

Aniline dyes are produced to-day in the United States in three to four times the quantity produced before the war. By 1916 enough dyes will be manufactured in the United States to take care of the entire demand.

Carbolic acid is another important product now manufactured in this country in large quantities.

As regards *napthaline*, 2,500,000 lb. per year were produced before the war. This year 8,000,000 lb. will be turned out—almost covering the United States consumption of 9,000,000 lb.

Barytes: The imports in 1913 amounted to 40,000 tons. Since the war started Tennessee (Toch Brothers), Missouri and other States practically supply the demand. The present duty of 15 per cent must be increased if this industry is to continue in this country after the war is over.

Carbon Tetrachloride: Before the war only one-half of the CCl_4 consumed in the United States was made here. By 1916 all of it will be made here.

Acids: The general situation in the acid manufacture and consumption is very serious. We cannot make anywhere enough to supply the demand.

Alkalies and *bleach* industries show a great prosperity. We can take care of the entire American demand. Much of the Prussian blue is now made from soda instead of potash.

Oxalic Acid: Most of the acid consumed in this country is now made here.

In conclusion Mr. Stone said that the status of the American chemical industry as a whole is very satisfactory, and the industry in this country is very prosperous.

Mr. MAXIMILIAN TOCH, partner of Toch Brothers, followed with an equally interesting and very encouraging paper on

"The Barium Industry in the United States Since the European War."—A little over a year ago there was no barium industry in this country. Germany and Austria have large mines of practically pure witherite, also cheap hydrochloric acid. It was impossible for American manufacturers to compete. This country does not possess similar rich mines and costs of labor, transportation, etc., are here much higher. Furthermore, the Governments abroad have subsidized the industry, enabling German and Austrian shipments to be unloaded here at $1.85 per ton (against crude United States barytes at $3 per ton).

However, barium salts have become an actual necessity in this country.

An important application of barium sulphate is in the gray paint of our battle ships; it resists the action of sea water and contains 45 per cent $BaSO_4$. Mr. Toch received the Government contract. To fill it, soon after the outbreak of the war, Mr. Toch went to Sweetwater, Tenn., and bought up the Gilman plant, now called the Durex Chemical Works.

Here at Sweetwater the mineral (barytes) occurs as a residual deposit, but not in such large masses as in Germany but in scattered small lumps. A large number of interesting slides of the deposits, mines, washers, furnaces, etc., were shown by Mr. Toch. Within a few weeks Mr. Toch expects to have the production increased to 32 tons of barium salts per day.

The barytes are mixed with coal and heated to bring about the following reaction:

$$BaSO_4 + 2C = BaS + 2CO_2$$

Fluorides, lead salts and other impurities prevent complete transformation into BaS or "black ash." This is subsequently fused with soda.

$$BaS + Na_2CO_3 = BaCO_3 + Na_2S.$$

The sodium sulphide by-product is sold to the dye manufacturers for making "sulphur black"; it competes easily with the Na_2S made by the reduction of Na_2SO_4 by coal. Barium salts are an important constituent of lithophone.

At present the salts are made in New York (on Long Island), but it would be cheaper to make them near the mines at Sweetwater, since zinc mines are close at hand there and labor and coal are abundant. It is interesting to note that Mr. Toch uses iron leaching tanks; FeS is formed on the surface of the iron which protects the metal underneath.

Mr. Toch emphasized that if the barium industry is put on a good solid business foundation with ample Government protection it will survive after the close of the European war. Industrial chemistry after all is 49 per cent chemistry and 51 per cent business.

In the discussion of the paper Dr. Doremus emphasized the importance of electric furnace methods for the reduction of barytes, and referred to the Jacobs process formerly carried out at Niagara Falls.

American Institute of Chemical Engineers

The winter meeting of the American Institute of Chemical Engineers will be held in Baltimore, Md., from Wednesday to Saturday, Jan. 12 to 15. The date selected is somewhat later than usual because the summer meeting was held late in August instead of June as is customary.

Excursions are being arranged to a number of chemical plants, Baltimore being a center of considerable industrial chemical activity. The experimental laboratories of Johns Hopkins University and the Naval Academy at Annapolis will also be visited.

Dr. John C. Olsen, Cooper Union, New York City, is the secretary of the institute.

Armco Iron Rust-Resisting Products and **Defeating Rust** are the titles of two interesting recent publications of the American Rolling Mill Co., Middletown, O.

Aluminium is the most abundant of all the metals. In the form of its oxide, alumina, it constitutes about 15 per cent of the earth's crust, according to the U. S. Geological Survey. Bauxite, however, from which aluminium is extracted by present commercial processes, is by no means plentiful, but known deposits are sufficient to make aluminium the important metal it is. The great future of this metal may lie in the perfection of a process whereby it can be commercially extracted from the unlimited deposits of alumina-rich clays and rocks in all parts of the world.

The Iron and Steel Market

The market pace in the steel trade has been rapid in the past fortnight. The scarcity of steel has been greatly accentuated, both by mills finding they were more oversold than they thought, and by demand broadening in several quarters, particularly in the line of railroad material.

The railroads are now definitely in the market for their steel requirements for 1916. They have already contracted for about 400,000 tons of rails, and with a further inquiry in the market the most vital needs of all the important roads will probably have been covered within another month. The railroads are not buying large individual tonnages of rails, their purchases being approximately equal to the average of the past two or three years, and their appearance in the market at this time is due simply to the fact that with so much rail mill capacity engaged in the rolling of large rounds for shells it is necessary to contract early to insure desired deliveries. Car buying is steady, although moderate. There is fairly heavy contracting for track supplies, at a time much earlier than usual.

There is a marked increase in the demand for steel from neutral countries, and exports of such material are likely to increase steadily from month to month, while the demand for steel from countries at war shows no abatement, covering not only munitions and material for munitions, but railroad and other material required really for war purposes, but somewhat less directly. Some South American countries are now taking more steel from the United States than they ever did in the past, marking a very decided improvement in this trade, as on account of industrial depression in South America the demand had decreased markedly during the twelvemonth before the war started.

Rates of Production

We estimate that at the middle of October pig iron is being produced in the United States at a rate of more than 36,000,000 tons per annum, contrasting with a previous maximum of 34,000,000 tons, reached in February, 1913. The steel interests have increased their pig-iron production by more than this amount, as the merchant furnaces are producing at a rate about 1,500,000 tons less than at their previous high record rate. We estimate the rate of production of steel ingots at between 38,000,000 and 39,000,000 tons per annum, against actual production of slightly more than 30,000,000 tons in each of the two best years on record, 1912 and 1913. The production of ingots is somewhat larger, relative to the production of pig iron, than normal, owing to the heavy cropping of ingots involved in the production of special steel required for war purposes. By reason of this heavy cropping of ingots, and by reason further of the heavy production of forging billets, also for the production of war material, the production of finished rolled merchant steel is an unprecedentedly small percentage of the total ingot tonnage.

Pig Iron

The pig-iron market has been practically stationary in the past fortnight. During the first six months of the year pig-iron prices were almost stationary, advances occurring in July, August and September averaging from $2 to $2.50 per ton in the different districts. The market the past fortnight has been distinctly less active than it was, on an average, during the first half of the year. The advances in recent months were due partly to sentiment, as steel prices were advancing, and as the slightly expanding demand required the blowing in of furnaces having higher costs than those already in operation. Now the pig-iron market awaits a fresh stimulus. There is ample production of merchant iron to meet all current requirements and as quite a number of merchant stacks could be blown in on short notice there is no uneasiness on the part of buyers. To cause another important advance in pig iron will require either a large increase in activity at gray and malleable iron foundries, or large buying of merchant iron by steel works, such as might, perhaps, be caused by their having been drawing upon stocks lately, or by some of their own furnaces being forced out of blast for relining. The steel works can hardly consume more pig iron than they have been consuming in the past two months. We quote: No. 2 foundry delivered Philadelphia, $16.25 to $16.75; f.o.b. furnace, Buffalo, $15.50 to $16; delivered Cleveland, $15.25; f.o.b. furnace, Chicago, $14.25 to $14.75; f.o.b. Birmingham, $11.50 to $12.50, the higher figure being for first half 1916; at valley furnaces, 95 cents higher delivered Pittsburgh; Bessemer, $16; basic, $15; malleable, $14.50 to $15, depending on manganese specification; No. 2 foundry, $14.50 to $15, depending on delivery; gray forge, $14.25 to $14.75, depending on delivery.

Steel

The market for ordinary soft steel open-hearth billets has disappeared, and Bessemer billets, the market quotation for which has been made chiefly by reference to the market for open-hearth, has not developed a clear cut market, but the commodity can be quoted roundly at $25 to $26, f.o.b. maker's mill, Youngstown. Neither Bessemer nor open-hearth sheet bars are really a market commodity now, as sheet and tin mills are covered largely by old contracts and have such selling prices, apparenty dictated by the cost of their steel, that they could not afford to pay prices that would be asked for sheet bars, which normally command an advance over open-hearth.

The disappearance of the market for ordinary soft steel open-hearth billets is due to the large demand there has been for forging billets, for making large shells, and for analysis billets for rolling large rounds for smaller shells, generally about 3-in. The most common specification for steel for rolling such rounds is not over 0.04 per cent sulphur, 0.04 to 0.08 per cent phosphorus and silicon, say 0.20 to 0.30 per cent or 0.30 to 0.40 per cent, with carbon 0.32 to 0.42 per cent in the case of French and 0.47 to 0.57 per cent in the case of English. The carbon is, of course, very ordinary for a carbon specification, the sulphur is not really difficult and the phosphorus is particularly easy. The silicon merely requires the proper blast furnace Bessemer ferrosilicon addition. The cropping varies, from a total of 20 or 25 per cent to a maximum of 40 per cent, 35 per cent top and 5 per cent bottom. The cropping usually must be done from the ingot, requiring sawing, and the ingots must be chipped to avoid seams that would be dangerous—at the wrong time—in the thin shell which is ultimately produced. These specifications involve no problem, yet as high as $45 is being paid for the billets. Naturally the mills able and willing to produce such steel have no occasion to quote on ordinary soft steel billets, as buyers could not think of paying such prices as they would be disposed to ask.

While the demand for steel billets of this character is heavy, there is another condition making steel particularly scarce as a market commodity and that is that a number of steel mills made a curious over-

sight in selling against specifications involving heavy cropping, in that they neglected to observe that their output ratings were referable to their ingot-producing capacity, the rating therefore including the material that is cropped as well as the material that is sold, and if a mill can produce 10,000 tons of ingots in a given time it cannot crop 25 or 30 per cent of the ingots and still have 10,000 tons of material to apply on the sales contract. A number of mills find themselves oversold through neglecting to observe this arithmetical fact.

Finished Steel

Finished steel prices are steadily advancing, in one commodity or another. The basis for present advances in finished steel is not the specifically heavy demand for this finished product or that, but the general scarcity of steel. In the large mills making a variety of products very few departments are allotted steel to their rolling capacity. Thus the bar mills may be breaking their records, rolling 110 or 120 per cent of their rated capacities, and being given steel to do so because the orders for bars are in hand for a run of six weeks or perhaps several months, while the structural mills may be allotted only enough steel to operate at 60 or 70 per cent, the structural mills perhaps having specifications for operating four or six weeks at this rate. Upon the wire mills there is special pressure. They are operating at an overload, filled with specifications in the barb wire departments for perhaps three months, with heavy specifications for plain wire and specifications for perhaps four weeks of output in nails.

Bars, plates and shapes for early specification and delivery at mill convenience, have advanced from 1.35c. to 1.40c. in the past fortnight, and while a few weeks ago 1.40c. was freely quoted on first quarter contracts this figure is now quoted with reserve, and some mills are practically refusing to quote for first quarter.

Current quotations, f.o.b. Pittsburgh, unless otherwise noted:

Rails, standard section, 1.25c. for Bessemer, 1.34c. for open-hearth, f.o.b. mill, except Colorado.

Plates, tank quality, 1.40c.

Shapes, 1.40c.

Steel bars and bands, 1.40c., base; steel hoops, 1.50c., base.

Iron bars, 1.559c. to 1.609c., Philadelphia; 1.35c., Chicago; refined iron bars, 1.45c. to 1.50c., Pittsburgh.

Plain wire, 1.60c.; galvanized wire, 2.30c.; painted barb wire, 1.90c.; galvanized barb wire, 2.60c.; wire nails, $1.75 base.

Sheets, blue annealed, 10-gage, 1.60c. to 1.70c.; black, 28-gage, 2.00c. to 2.10c.; galvanized, 28-gage, 3.50c.; painted corrugated, 28-gage, 2.30c.; galvanized corrugated, 28-gage, 3.55c.

Tin plate, $3.10 to $3.20 for 100-lb. cokes.

Steel pipe, ¾ to 3-in., black, 79 per cent off list; galvanized, 63½ per cent off list.

Boiler tubes (less than carloads): Steel, 71 per cent off list; iron, 60 per cent off list.

Structural rivets, 1.60c.; boiler rivets, 1.70c.

The unfilled obligations of the United States Steel Corporation at the close of September are reported at 5,317,608 tons, representing an increase during September of 409,153 tons, against a loss in August of 20,085 tons. September shipments may be estimated at 95 per cent of rated capacity (at about 47,000 tons daily), the increase in obligations representing 35 per cent of capacity, so that the bookings appear to have been 130 per cent of capacity.

American Institute of Metals

The annual meeting of the American Institute of Metals was held at Atlantic City, N. J., Sept. 28 to 30 inclusive, in conjunction with the convention of the American Foundrymen's Association. The attendance was very good, the natural advantages of Atlantic City at this time of the year probably inducing a great number to enjoy the convention.

The tenth annual Foundry and Machine Exhibition which was held on Young's Pier as a part of the convention was opened on Sept. 25 and continued to Oct. 1. The exhibition was representative of the great progress of the metal working industries during the past few years. On Tuesday morning, Sept. 28, a joint session of the American Institute of Metals and the American Foundrymen's Association was held in the Greek Temple on Young's Million Dollar Pier.

The American Institute of Metals held its first independent session Tuesday afternoon at the Hotel Traymore. The paper by GILBERT RIGG and HENRY C. MORSE on "The Influence of the Impurities of Spelter on the Cracking of Slush Castings" brought out some discussion in which it was concluded that cadmium produces a hot short condition in zinc which renders it unfit for castings. Lead produces a bad effect also, in making heavy castings. Arsenic has little or no effect in the small amounts usually found. A paper on "Standard Test Specimens of Zinc-Bronze" was presented by Dr. H. S. RAWDON of the Bureau of Standards. Dr. G. K. BURGESS read a paper on "An Investigation of Fusible Tin Boiler Plugs" which was abstracted in this journal Sept. 1, page 568.

On Wednesday morning the session was opened by a paper on "The Effect of the Present European War on the Metal Industries," by THOMAS F. WETTSTEIN. The discussion brought out the fact that a great number who had been using Lake copper were forced to experiment with electrolytic with the result that very few would go back to the use of Lake copper as long as there was such a wide difference in the prices. The subject of "sherardizing" was illustrated by a number of diagrams sent by the General Electric Company.

On Wednesday afternoon the session was given over to the discussion of aluminium and its alloys. A paper by CHARLES PACK on "Aluminium Die Casting a Commercial Achievement" discussed this important use of aluminium. A paper on "Melting Aluminium Chips" by Dr. H. W. GILLETT discussed the difficulty, on account of a thin film of oxide on the chips formed when they were cut. Two commercial methods were given in detail. A paper by W. M. CORSE on "Auminium-Bronze Alloys" took up the remarkable changes in hardness which can be brought about above 7 per cent of aluminium and discussed the commercial possibilities of these alloys. Other papers presented were "The Autogenous Welding of Aluminium" by E. V. PANNELL and "The Manufacture and Use of Alumino-Vanadium" by W. W. CLARK.

Papers presented at other meetings of the Institute included a paper on "An Acid-Resisting Alloy" by S. W. PARR. An alloy was found and described which would withstand the continued action of nitric acid without loss. Two papers on brass were read, viz: "Some Experiences with Brass in Civil Engineering Works" by A. D. FLINN, "The Failure of Structural Brass" by Dr. P. D. MERICA. We reserve fuller accounts of a number of the papers presented for future issues.

At the business meeting of the Institute Mr. JESSE L. JONES of the Westinghouse Electric & Manufacturing Company was elected president succeeding Mr. G. H. Clamer. Mr. W. M. CORSE of the Titanium Alloy Manufacturing Company was re-elected secretary.

The Range of Applicability of the Liquid Sulphur Dioxide Method for Determining Aromatic Constituents in Hydrocarbon Mixtures[1]

BY W. F. RITTMAN AND R. J. MOORE

One of the most convenient and widely used methods of separating the constituents of liquid mixtures is that based on differences of solubility in some reagent. To make this method effective it is necessary that these differences shall be considerable and that the solvent shall be easily removable from each of the two fractions after the extraction has been accomplished.

When used at sufficiently low temperatures liquid sulphur dioxide has the property of dissolving readily aromatic and unsaturated hydrocarbons and leaving unaffected the saturated paraffins and naphthenes. In addition, it is easily removable from hydrocarbons, either by evaporation or by washing with an aqueous alkaline solution.

On the basis of these properties Edleanu[2] has developed a commercial process for the refining of petroleum and also has worked out the details of a laboratory method of analysis. His problems were in the line of estimating aromatic constituents as impurities in ordinary petroleum mixtures and he records the obtaining of excellent results.

In connection with work on the production of aromatic hydrocarbons by the cracking of petroleum methods of analysis and separation were sought which should be reliable, accurate and convenient. Results of the major portion of these researches are recorded in another communication.*

The present note describes some experiments in which the liquid sulphur dioxide method was tried out with known mixtures. The results obtained were sufficient to indicate clearly the range of applicability as regards concentration of aromatics.

Experimental

Mixtures were made up which contained known proportions of aromatic and non-aromatic constituents. For the former was used a mixture of 16 per cent cymene, 42 per cent xylene and 42 per cent toluene. This mixture had a specific gravity at 15 deg. C. of 0.874 and a refractive index of 1.494. The paraffins were represented by a gasoline of specific gravity 0.720 and refractive index 1.400, which gave no coloration when treated with a mixture of nitric and sulphuric acids. The known mixtures were made up on a basis of percentage by volume.

The experiments here described were performed by a modification of the Edleanu method which seemed to be sufficiently accurate for present purposes. Apparatus consisted of a fifty cubic centimeter graduated tube equipped with well ground glass stop-cocks at either end, a jar to contain cooling mixture and a small tank of liquid sulphur dioxide. The apparatus is shown in Fig. 1.

The mixture to be tested was introduced into the graduated tube and the latter immersed in a cooling mixture of ice and salt. Connection was made with the sulphur dioxide tank by means of a length of heavy walled rubber tubing, the valve was opened and the gas allowed to distill over into the oil. After the latter became saturated, a second (lower) layer appeared which consisted of liquified sulphur dioxide, holding in solution the aromatics. The two layers were separated by running out through the lower stop-cock and the sulphur dioxide slowly boiled off until a temperature of 50 deg. C. was reached. This method of procedure undoubtedly was responsible for a certain amount of loss which could have been avoided in case it were necessary by the washing with aqueous alkaline solution recommended by Edleanu. Specific gravities and refractive indices were determined for the residues from both layers. Their quantities were of course measured.

The results of experiments with mixtures of varying composition are shown in Table I. It appears that with a concentration of aromatics not exceeding 25 per cent, separation may be obtained by the use of sulphur dioxide at temperatures in the neighborhood of — 20 deg. C. The separation was not, however, satisfactory at concentrations exceeding 15 per cent, as above this point there are no good figures for percentages and physical constants of the fractions separated. The matter of temperature once more was shown to be of great importance. As the two layer system, obtained in the graduated tube, is permitted to warm up the line of demarcation becomes blurred and finally disappears when temperatures in the neighborhood of 10 deg. to 15 deg. are reached.

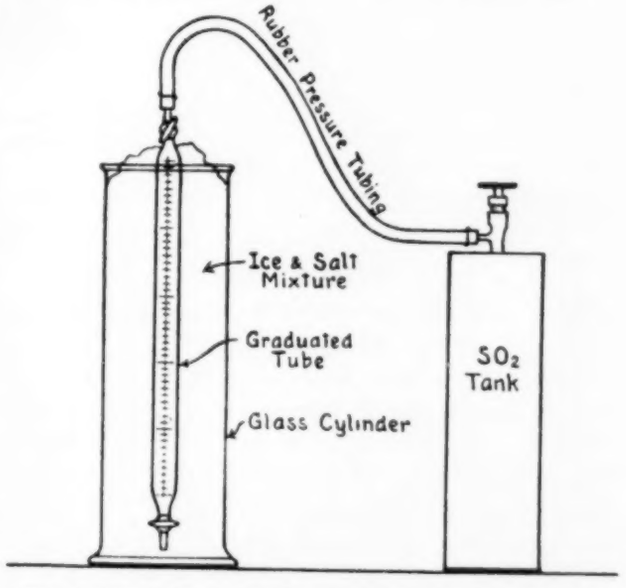


FIG. 1—APPARATUS FOR SULPHUR DIOXIDE SEPARATION

TABLE I.

SULPHUR DIOXIDE SEPARATION OF KNOWN MIXTURES

Constituents used:

Paraffin—A gasoline giving no coloration with nitric-sulphuric acid mixture. Specific gravity 0.720. Refractive index 1.400.

Aromatic—A mixture of 16 per cent cymene, 42 per cent xylene and 42 per cent toluene. Specific gravity 0.874. Refractive index 1.494.

Exp. No.	cc Mixture	cc SO_2	Temp. C., Deg.	Per Cent Arom.	Total Per Cent Arom. and Non-Arom. Recovered	Per Cent Arom. Separated
1	16.0	24.0	— 20	15.0	98.2	14.3
2	16.0	25.0	— 20	18.0	94.4	16.3
3	14.0	20.0	— 19.5	20.0	90.0	15.0
4	14.0	19.0	— 20	25.0	Hazy separation	
5	14.5	20.0	— 19.5	30.0	No separation	
6	12.5	18.5	— 20	50.0	No separation	
7	14.0	19.0	— 19	60.0	No separation	
8	14.5	19.5	— 20	67.0	No separation	
9	14.0	20.0	— 20	75.0	No separation	

COMPARISON OF PROPERTIES OF ORIGINAL AND SEPARATED HYDROCARBONS

Hydrocarbon Sample	Sp. Gr. Non-Arom.	Sp. Gr. Arom.	Ref. Index, Non-Arom.	Ref. Index, Arom.
Original	0.720	0.874	1.400	1.494
Exp. No. 1.....	0.722	0.870	1.410	1.491
Exp. No. 2.....	0.723	0.869	1.415	1.490
Exp. No 3.....	0.751	.....	1.425	1.485

[1]Published with the permission of the Director of the Bureau of Mines.

[2]Bull. Am. Inst. Min. Eng., Sept., 1914, page 2313.

*Rittman, Twomey & Egloff, Metallurgical and Chemical Engineering, October, 1915.

Edleanu records obtaining at — 10 deg. separation with a mixture containing 40 per cent of aromatics. With the hydrocarbons used in the present experiments the limit seems to be much lower. Multiple extraction, as recommended by Edleanu, would undoubtedly improve results between the limits of 15 per cent and 25 per cent, but it is difficult to see how this device could help when a first extraction failed to obtain separation into layers.

Summary

1. It has appeared that although the liquid sulphur dioxide method works well for the estimation of small quantities of aromatics in hydrocarbon mixtures it is not applicable if the content exceeds a limit in the neighborhood of 25 per cent.

If it is desired to determine aromatics by this method when the concentration is greater, use must be made of the device of diluting with a pure paraffin mixture such as water white Pennsylvania kerosene. Diluting with an equal volume will bring mixtures containing from 25 per cent to 50 per cent below the limit of separation. Dilution with three volumes of the paraffin will take care of oils whose aromatic content ranges between 50 per cent and 100 per cent.

2. Temperature at which extractions are performed must be low, preferably in the neighborhood of — 20 deg. C.

The experiments here described were performed in the laboratory of the Department of Inorganic Chemistry of Columbia University, New York.

Chemical Section of the Petroleum Division, U. S. Bureau of Mines, Pittsburgh, Pa.

Liquid Jets

A Study of a Phenomenon of Importance in Flotation and Cyanidation

BY C. TERRY DU RELL

The whole subject of flotation depends upon gas absorption. The mineral to be saved as a concentrate must have occluded sufficient gas to prevent its being wetted by the flotation liquid. Once wetted with the flotation liquid, its tendency is to sink as there can then be no surface tension effect tending to float it. The flotation liquid may be assumed in all cases to be water as it has been proven that no liquid except mercury has such great surface tension. Water will enter the pores of a solid from which all gas has been driven out and adhere to the surface so that the solid becomes as a part of the liquid so far as surface tension effects are concerned. That is, if there is a force of adhesion existing between the molecules of the water and the molecules of the solid, flotation cannot take place. If the particles be on the surface of the water, this truth is readily seen when an attempt is made to float them with say a Henry Wood type of machine, but it is not so readily seen when an attempt is made to float them by means of bubbles or froth if the particles be below the surface of the water.

Hereinafter then, only flotation of submerged particles will be considered. If a particle is to be floated by means of minute bubbles, these bubbles must be attached to the particle; or, if it is to be floated by means of froth, the particle must be attached to a bubble. The surface tension of a liquid film surrounding a gas bubble, being much greater than the adhesive force between a gas and a solid, holds the gas firmly inside the film so that attachment in this case between the gas and solid cannot take place. It is easily proven that gas, to be attached to a solid in a liquid, must be in a nascent state in the liquid. On being driven out, it will collect in the form of bubbles. It is therefore quite evident that, if the solid contain some of this gas, it will be a nucleus for the collection of these bubbles due to cohesive force existing between molecules of gas at the surface of the solid and molecules of gas in the liquid immediately surrounding the solid. Since air is readily soluble in water (especially the oxygen) and also since it is occluded by most solids, due especially to the chemical affinity of the oxygen, it is by far the most preferable gas for flotation as well as the cheapest, and will be hereafter the only one considered.

Due to the fact that air is soluble in oil and that oil is practically insoluble in water, it is readily seen that gas can be much easier attached to oiled mineral particles. Molecular attractions only being considered, the thinnest possible film of oil is all that is necessary. "Oil prevents the wetting of mineral particles" is evidently an erroneous statement since it is common practice to oil-coat the mineral particles while they are in the water. The particle contains gas and therefore can be oiled. Due to the cohesive force of the oil, a film may be formed which adds strength to the water film and prevents the bubbles from bursting so easily.

By the addition of an acid or an alkali to the water to form an electrolyte, an ionized condition is produced which creates a selective action of flotation due to occlusive power of at least some of the minerals being affected.

Role of Air in Flotation

After examination of all the different materials used in connection with flotation, it is seen to depend entirely on, first, dissolving air in preferably an electrolyte as well as in the ore and, second, the expulsion of this air. This all depends on Henry's law.[1] From this law it is readily seen that air may easily be expelled from either the electrolyte or ore particles[2] by heat or reduction of pressure.

It is evident that it makes no difference whether the gas be absorbed at high pressure and liberated by reduction to atmospheric pressure or absorbed at atmospheric pressure and liberated by vacuum. Naturally then the fundamental requisite for flotation is the production of a state whereby both water and mineral will absorb air. This eliminates any process in which air, dissolved at atmospheric pressure and temperature, is liberated by a vacuum, as such a process, necessarily limited to low altitudes, is crude and full of too many mechanical difficulties which make it unnecessarily expensive to operate. This has been the experience of plants operating by such a method.

According to the law of Henry, it would be possible, by varying temperature and pressure, to make water absorb its own volume of air since, for instance, at 10 deg. C. it is known to dissolve 2 1/3 per cent of its own volume at sea level. As an example, it would be quite easy to subject the water to say 90 lb. pressure per square inch or six atmospheres when, at the ordinary mill water temperatures of 10 deg. C., it would dissolve 15 per cent of its volume of air. As this requires some power, it is well to investigate the quantity necessary to be dissolved to effect flotation. That is, what degree of saturation is necessary?

As noted above, it is only the air that is driven out of solution or nascent air that can be used for bubble making or flotation. These bubbles, on coming to the surface, tend to burst, due to expansion, etc. Then the greater the pressure of the gas in the bubble the greater will be this bursting tendency. Therefore it would seem desirable to form these bubbles at com-

[1] At constant temperature, gas dissolved in a given volume of liquid varies directly as the pressure. Each gas is dissolved independently of all other gases.

[2] Cook's Chemical Physics. Solution of gases.

parative shallow depths in the water and with as little pressure as possible. In other words, mere supersaturation of the water with air near the water surface.

Supersaturating Liquids with Gases

A simple way to supersaturate water with air at atmospheric pressure is to beat it in with paddles or stirrers. The Minerals Separation Co. has patents describing this means. "Beating air into solution" does not well explain just what action takes place. To study this, take the simplest case of a single paddle, say a piece of wood partly submerged in water. Move it rapidly through the water. The instant the water is divided, a film of air forms on these division walls. As the water closes in again behind the paddle, this air film is taken into the interior of the water. Being a mere film, it is absorbed. The water, being already saturated with air, cannot hold any more so the excess must come out in the form of bubbles.

If there be paddles or blades on a shaft revolving rapidly below the surface of the water, a vortex is created and the water, on going down to take the place of that thrown out from the ends of the blades, carries air in with it as a film on the surface. It is readily seen that surface tension is the cause of this air being carried in and absorbed by the water. If the bubbles form fast enough, froth is produced, especially if there be sufficient material present to coat and toughen the bubbles.

This is a common method for getting air into solution and of every day occurrence. Eggs are beaten to a froth and the bubbles toughened with sugar. A small boy drags a stick rapidly through the water to see the bubbles in its wake. The water astern from a ship is white with the reflection of light from the air bubbles of supersaturation caused by the propeller. The surface tension at the crest of a wave, on "breaking," causes the air to be absorbed and given out as bubbles.

Another way of supersaturating a liquid with a gas has hitherto not been taken advantage of in flotation. Common occurrences of this are to be noted as well. On drawing water from a tap into a wash basin for instance, bubbles are seen to form and rise to the surface. Where does this air come from? If water from a hose be turned by means of a nozzle into a bucket some little distance away, a froth is formed. Fish in an aquarium rise to the surface for want of air. The attendant opens a jet of water fixed a short distance above the surface. This water shoots down into the aquarium, a stream of bubbles rise to the surface and the fish goes back to the bottom satisfied.

A stream of pulp is turned into a thickening tank from some little distance above, either directly or through a pipe straight down and below the surface and the millman is driven distracted by the froth that forms and causes a muddy overflow. It is then necessary to fit an interior ring as a barrier against the bubbles in order to obtain a clear overflow.

These phenomena are therefore worthy of investigation as air can apparently be taken into solution this way as well as with paddles or stirrers. This may be classified and defined as streams of liquid projected through a gas and into a liquid. The term liquid jet is applicable as it is a phenomenon of a jet of liquid as shown by the cited examples.

Phenomena of Liquid Jets

In investigating this. it would be well to first investigate the injection of a liquid into a gas. The liquid may be injected (1) vertically upward, (2) vertically downward or (3) at an angle. With a jet turned straight down, gravity is bound to accelerate the fall of the liquid. At some distance from the nozzle, the liquid will be traveling faster than that portion leaving the nozzle, due to this acceleration. This, it is seen, will tend to break the stream up into short cylinders and stretch the intervening liquid into long thin cylinders. Further acceleration will break these larger portions off. Surface tension, having rounded the edges previous to their breaking off, will immediately form them into drops and at the same time form smaller drops from the long thin cylinders in between. Thus there will be a falling succession of drops alternating large and small. The surface tension of the air film is so great that these small spheres are formed. Pictures have been taken showing this action in detail.

With the jet turned straight up, gravity retards the stream so the velocity becomes less as the distance from the nozzle increases. The whole stream is surrounded as before with an air film, the surface tension of which carries it along. When the gravity plus the weight becomes equal to the initial pressure, portions must be forced out sideways and spherical drops formed as described above. The surface tension of the surrounding air films prevent their re-uniting so that they will actually rebound from one another.

With a jet turned out at an angle (horizontal or inclined), gravity retards and pulls the stream down until portions are broken off to form spherical drops. The viscosity of a liquid tends to counteract this so that glass, for instance, can be spun or drawn out into threads.

The intensity of this surface tension effect may be shown by directing a jet of water onto an oiler or dusted surface when the globules of water will be held intact and roll the same as if they were enclosed in a solid substance when, in reality, they are only enclosed in a "skin of air."

The jet of liquid before breaking up was thus seen to be enclosed in a cylinder of gas, the surface tension of which caused it to move with the liquid and at the same velocity. The rush of air into a large nozzle to form this enclosing air cylinder may be readily felt by the hand. In other words, a jet of liquid turned into a gas does not merely slide through that gas or a cylinder of that gas but carries the "gas cylinder" along with it.

If the jet of liquid, passing through a gas, be turned into the surface of a liquid, the enclosing gas cylinder is evidently carried into the liquid and, if the liquids mix or are soluble in each other, the gas must be liberated. That is, the cohesion or adhesion, as the case may be, of the liquid jet for the liquid it has penetrated is sufficient to overcome the surface tension of the gas cylinder. The gas, being in such a thin film, is so finely divided it enters in between the molecules of the liquid in the interstitial spaces, and, if the liquid is not already saturated, remains there. A jet of gas entering a liquid, would, due to this surface tension effect, act the same as a jet of liquid entering a gas.

A simple way to prove that this gas cylinder goes into solution is to turn a jet of water into a vessel of water that has been boiled and cooled. On reheating, air will be expelled from the water in this vessel while none will be expelled from a similar quantity of water into which no jet has been turned.

When a liquid is entirely saturated with a gas brought in with a jet, supersaturation has the effect of producing nascent gas which collects in the form of bubbles. This fact is taken advantage of for flotation and will eventually be put to many other uses.

At the present time, this principle is used to a large extent for the hydraulic compression of air, where the surface tension causes the air film to be entrained and carried down a pipe of shaft to be liberated at the bot-

tom in a chamber under pressure. Frizell, although not recognizing this principle of air introduction with his air compressor design, does recognize the fact that it is not necessary to have a large number of small air inlet pipes at the intake. The simplest form is used for ventilating mines and, since oxygen is more soluble in water than nitrogen, the liberated air contains nearly 35 per cent oxygen against less than 21 per cent oxygen in the air introduced by a blower, for instance.

Importance in Cyanidation

It seems strange that this liquid-jet phenomenon has not been recognized before by many cyanide metallurgists since it has been the direct cause of many cyanide plant failures. Visit any old or modern cyanide plant and see the numerous jets of solution passing through the air and into a tank of solution. Pumps deliver streams here and there and through the air into tanks of solution or of pulp. Everything is supersaturated with air.

With sand leaching, this does not prevent operations being carried on, although, with some ores, an extra cyanide and lime consumption results. The millman simply remarks that the ore has a latent acidity, dumps in more cyanide and lime and lets it go at that. He does not bother with a reason for certain contained minerals being rapidly oxidized.

However, it is with the slime that big troubles occur. When the slime is very fine, and settlement and filtration difficulties are experienced, the millman, knowing it is not a crystalloidal slime, assumes that it must be a colloidal slime and that settles the question though not the slime. Simple logic this. It must be one of two things. Therefore, since it is not the one, it must be the other. The last few years, many cyanide metallurgists seem to think only of "the gel state" or "the sol state" and seem to have forgotten that a state of suspension can exist so that a pulp may only resemble a colloidal state.

This excess air coming out of solution is attached to even the smallest particles of slime as well as the larger particles. The larger ones can perhaps settle in spite of this buoyant tendency while the smaller ones may not show the slightest tendency to settle. It is a well known fact that settlement of the particles or of a precipitate takes place rapidly after the solution has been boiled and cooled. The only effect of the boiling is to drive out the air.

In many cases, when a solution of water stands until it appears perfectly clear, boiling and cooling will show an appreciable sediment on the bottom of the container.

It is certainly extremely difficult to thoroughly mix a pulp ready for filtration when some of it is floating, due to air bubbles, and the balance settles out readily. Much trouble is thus caused with the cake on a vacuum machine as well as in a press.

Plenty of trouble is caused in a cyanide plant when the bubbles are practically microscopic but great difficulty has been experienced at some plants where the bubbles were quite large and at a few where froth formed.

It seems doubtful if there is a single case of difficult slime settlement due entirely to a true colloidal condition as most pulp solutions are so supersaturated with air that they are more nearly ready for a flotation plant than they are for a cyanide plant.

Los Angeles, Cal.

Comparative Tests of Piston-Drill Bits is the title of the August, 1915, Bulletin of the University of Missouri School of Mines and Metallurgy. The authors are Prof. C. R. Forbes and L. M. Cummings.

Notes on Concentration at Nevada Consolidated Copper Co.

(Editorial Correspondence)

In common with other large Western producers of copper, the Nevada Consolidated Copper Company has been pushing work to the limit of plant capacity. The concentrator, which ordinarily has handled an average of 1000 tons per day in each of the eight sections, is now treating a total of over 10,000 tons per day. From 3 tons to 4 tons of water is required per ton of ore treated, fluctuating with changes in the character of the ore, so that the problem of securing an adequate water supply has made it necessary to resort to various means of recovering water that might otherwise go to waste. With some changes and improvements now contemplated, to be mentioned later, it is expected that the water requirement will be reduced and that the present supply will be ample.

At the present time the water piped from Duck Creek is supplemented by spring water pumped up from the valley, and some water is recovered from tailing ponds. Dorr thickeners, however, are playing the important part in the latest plan for water conservation, because they simultaneously recover a large volume of water and thicken a dilute slime for the flotation machines. The recovered water is used as a wash for concentrating tables. Some very slimy water, containing from 10 per cent to 15 per cent solids, is used at the smelter for granulating reverberatory slag. Eight 50-ft. Dorr thickeners have been in use at the mill for some time, and four more, 70 ft. in diameter, have been recently added.

Thickeners Operating in Earth Excavations

These are erected in the open on a bench of ground behind the mill, with only a small housing for the individual 3-hp. motors, and embody a number of interesting features conceived and executed by Mr. George C. Riser, mill superintendent. Wishing to reduce the cost of construction as much as possible, he dispensed with the usual wooden tanks and excavated a suitable opening in the earth in which to operate the thickener mechanism. The sides of the earth "tank" slope 45 deg. from the circumference toward the center, as shown in Fig. 1. Around the circumference a narrow bench is excavated to support a concrete collar that forms the overflow launder and supports the weir. The detail of this construction is shown in vertical section in Fig. 2. Bolts are embedded along the inner edge of the collar to secure pieces of wood for attachment of the weir. In the same manner pieces of pipe embedded along the uppermost surface form a support for an iron-pipe railing that surrounds the finished thickener. The trusses are supported on 12-in. I-beams resting on concrete

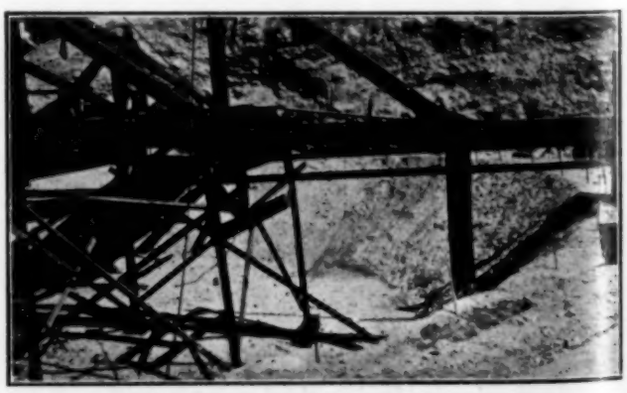


FIG. 1—EARTH EXCAVATION OF 70-FT. DORR THICKENER

piers. Fig. 3 shows a completed thickener operating in an earth excavation. This thickener gradually forms its own impervious walls and bottom of fine slime and no trouble is experienced from seepage. The 8-in. pipe for discharge of thickened slime is embedded in the bottom of the excavation and extends through the earth wall, issuing on the slope of the bench of ground in which the excavation is made. A similar pipe carries off the overflowing clear water.

The feed to these thickeners is carrying about 5 per

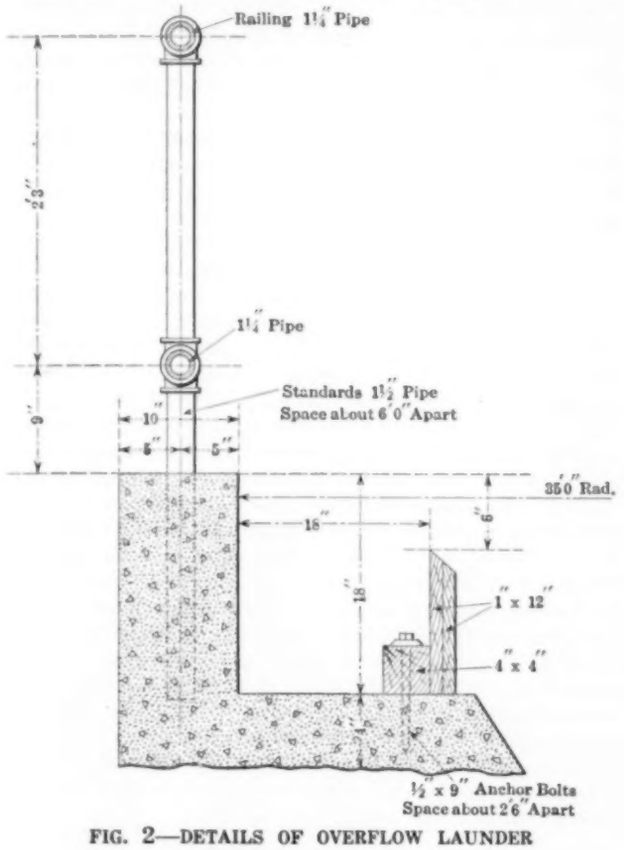


FIG. 2—DETAILS OF OVERFLOW LAUNDER

cent solids, and the discharge about 30 per cent. The only measurement of water recovery, made shortly after one of the thickeners was put in operation, indicates a recovery of 3 sec.-ft. for each 70-ft. thickener.

Changes in Grinding Practice

A number of changes are to be made in the present methods of grinding and concentrating which will greatly simplify the practice, increase capacity and recovery, and reduce the quantity of water required. For the present no change will be made in primary crushing, but rolls are to be abandoned for secondary crushing and fine grinding replaced with Hardinge ball mills. One section of the concentrator is to be remodeled for this experiment.

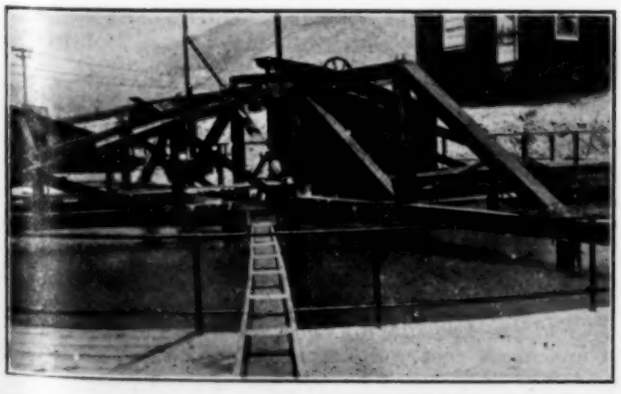


FIG. 3—COMPLETED THICKENER OPERATING IN EARTH EXCAVATION

In the present system the gyratory product is crushed in rolls, elevated and screened in trommels making two sizes for regrinding, 5/16 in. for return to coarse rolls and 3/16 in. to fine rolls. The product of the latter is elevated to 2-mm. trommels, the oversize of which is returned. The undersize flows to a four-compartment classifier. First and second classifications are treated on Wilfley tables, the tailings being reground. Third and fourth grades are similarly concentrated, the tailings being wasted. The classified overflow is thickened and treated by flotation in Janney machines. The reground Wilfley tailings are again classified into four products and treated on further Wilfley tables, all making final tailings except those handling the fourth classification, the tailings from which are treated on vanners.

In the section to be remodeled the rolls will be supplanted by Hardinge ball mills and the ground product elevated directly to classifiers. All grades plus 40-mesh will be treated on Wilfley tables as before, while the minus 40-mesh material will be treated by flotation. The tailings from the Wilfleys will be reground and also floated, vanners being eliminated in this section. The new plan offers obvious advantages over the old, both in the preparation of the ore and its treatment. The simplifying influence of flotation is seen in the elimination of some Wilfley tables and all vanners, and is the most important aspect of the proposed change. The changes in grinding will result in less handling of pulp and the use of less water.

Coal-handling machinery is in the August issue of the *Labor Savor*, a pamphlet by the Stephens-Adamson Mfg. Co., Aurora, Ill.

Sirocco Service, a pamphlet published by the American Blower Co., Detroit, gives many facts regarding the different uses of Sirocco Blowers.

Talc and Soapstone.—The United States produces more talc and soapstone than all the rest of the world combined, the 1914 production being 172,296 short tons, valued at $1,865,087.

Lump fluorspar for the manufacture of hydrofluoric acid showed an increase of 55.8 per cent in quantity and 91.3 per cent in value of sales in 1914 over 1913, according to U. S. Geological Survey.

Cyanides.—In the twelve months ending March, 1914, Canada imported 1,165,490 pounds of potassium and sodium cyanides and 166,901 pounds of yellow and red prussiate of potash.

Tin.—According to Mineral Resources of the U. S. there were no domestic tin ores smelted in the U. S. in 1914, though some tin concentrates were shipped from Nome, Alaska, to Singapore for treatment, and there was considerable agitation for the domestic smelting of both Alaskan and Bolivian tin ores. An increased output from Alaska may result in the establishment of a tin smelter on the Pacific Coast.

Primary Mercurial Resistance Standards.—The Bureau of Standards has just issued Scientific Paper 256, dealing with the construction of four standard ohms in the form of mercury columns in glass tubes, and the work involved highly accurate measurements. Comparisons of the four standards showed the average deviation of their individual values from their mean value to be less than one-one hundred thousandth of an ohm. England, Germany, France, Russia, Japan and the United States now have mercury standards of resistance which all agree to a high accuracy.

Thermal Principles of the Blast Furnace

BY J. E. JOHNSON, JR.

The doctrine of the conservation of energy and the interconvertibility of its forms was well established about the middle of the last century, but the latter was well in its third quarter before any systematic effort was made to apply that doctrine to the blast furnace.

This was first done by Sir Lothian Bell, who had made in his works-laboratory countless experiments conducted with a degree of scientific skill and breadth of vision rare in that day. With the results of these and the data on thermal capacities, heats of reaction, etc., so carefully and laboriously determined by the physicists of various countries, particularly France, he prepared a heat balance of the furnace showing the quantity of heat developing and the amounts utilized and lost in various ways, which was the beginning of any comprehensive knowledge of the subject, for without a knowledge of the theoretical amount of heat necessary to bring about the desired reactions in the furnace it is impossible to say whether we are getting a reasonable efficiency from the fuel or not.

Since that time heat balances without number have been prepared and used to prove any contention that it might please the fancy of their makers to uphold, but frequently without carrying much conviction. The reason for this was that while taking careful account of the quantity of heat they ignored the quality factor, that is, temperature-head or intensity. It was as if a hydraulic engineer tried to figure the water-power obtainable at a given site by accurate and painstaking determinations of the quantity of water passing without any regard to the head, or an electrician were to try to figure the power of a given circuit from the amperes of current without respect to its voltage, or more accurately still as if a steam engineer tried to figure the power he could obtain from a definite quantity of steam without knowing the temperature, on which its pressure depends.

This condition is all the more curious because in the case of the other great application of heat, the steam engine, the importance of the intensity factor was worked out and stated in mathematical language many years before the doctrines of the conservation and convertibility of energy were discovered, and both of these were known and the theory of the steam engine was complete, virtually in its present form, about the time Sir Lothian Bell's work on the heat balance of the blast furnace was begun.

This theory of the steam engine was completely enunciated by two laws known as the First and Second Laws of Thermodynamics. These may be expressed for our purpose as follows:

1. The quantity of work produced by transformation of heat bears a definite and unchanging ratio to the quantity of heat transformed.

2. The proportion of any given quantity of heat which can be utilized for conversion into work depends upon the temperatures at which the heat is applied and discharged.

The first of these laws is simply a special form of the law of conservation of energy, and by substituting "chemical change" for "work" it would express the law of the blast furnace which Sir Lothian Bell and his followers understood. But that the blast furnace depended also upon a similar "second law" was totally beyond their knowledge, although it is just as important in this case as in that of the steam engine. This accounts for the failure of the elaborate calculations based on the first law alone, to explain many of the well-recognized phenomena of blast-furnace practice.

For instance, the introduction of the hot blast reduced the fuel consumption of soft-coal furnaces more than a half, although the heat of the blast introduced was only about 18 per cent of the total produced—a preposterous state of affairs viewed only in the light shed by the heat balance—and Sir Lothian Bell spent not pages, but chapters, in trying to prove that the benefit of the hot blast was strictly limited, and was, in fact, smaller than it was generally known in practice to be, because he could not make the facts square with his incomplete theory.

This is a subject with which I have had some connection in its later development, and it may not be amiss to treat this portion of it from a somewhat personal point of view.

The explanation of the hot blast given in Sir Lothian Bell's works did not seem to me to explain, and I had, moreover, been puzzled by the action of moisture in the blast, a subject treated by him in a similar way, because I had for a number of years been studying that subject carefully and keeping records of humidity in the engine room, which showed that the moisture present in summer above that present in winter was sufficient to account on that basis for only 4 or 5 per cent difference in fuel consumption, whereas the furnace records over a number of years showed 20 per cent difference. In 1899 it began to appear to me that there might be a critical temperature in the blast furnace above which some of the heat had to be supplied, and that as the range between this temperature and the theoretical combustion temperature was only a fraction of the latter, a change in the latter would have an effect on this range (which obviously measures the amount of such heat available), several times as great as the effect on the theoretical combustion temperature. I did not then know what the critical temperature was nor what controlled it, but calculations on this basis with assumed critical temperatures based on the best information obtainable as to the temperature inside of the furnace, seemed to show a better agreement with the facts than did Bell's figures, and this idea grew in strength.

In 1901 a "Lunette" optical pyrometer was procured and observations of temperature made through the tuyeres, and in every other way thinkable, to determine what the critical temperature really was, because as long as it was only assumed it could be arbitrarily chosen so as to bring results which would agree with practice, but which would mean nothing.

The results of these observations revealed the fact that there was a critical temperature, that it was controlled exclusively by the free-running temperature of the slag, and that this temperature for the furnaces under observation was about 2750 deg. Fahr. A totally different investigation revealed the fact that the result of the removal of the moisture from the blast was identical in principle with that of the hot blast, and that its effects could be figured in exactly the same way.

Calculations of heat available above this critical temperature of 2750 deg. under different conditions of blast temperature and humidity agreed with the relative coke consumption under those conditions so well as almost to arouse suspicion of the possibility of self-deception, but the same principle seemed to work quantitatively under the most diverse conditions and to explain many facts not adequately explained before, and I became convinced it was correct.

The idea is so simple that it seemed almost sure that it must have occurred to some one else long ago, and I made the best search I could through the blast-furnace literature of four countries to see if this were true without finding a trace of it anywhere.

I wished to obtain certain patents founded on this principle so kept it secret for three years, until the summer of 1904.

At that time the patents desired were allowed and the preparation begun of a paper to set forth this new theory of blast-furnace action.

In that autumn Mr. James Gayley published his paper describing the actual results he had obtained at the Isabella Furnaces by the application of his system of drying the blast.

This was most fortunate for me, as it supplied authentic data strongly confirmatory of the new theory which were totally inexplicable by the old, and would, as I supposed, hasten the acceptance of the former, for it never occurred to me that the publication of Mr. Gayley's results would arouse any doubts of their correctness or any other sentiment except admiration for the solution of a problem of which all furnacemen must be aware and for which they must desire a solution. As a matter of fact, the announcement of Gayley's results set the whole metallurgical world into a furore, many furnacemen and near-scientists refused to accept the results, and even went so far as to question the correctness, not to say truthfulness, of the furnace records.

My paper entitled "Notes on the Physical Action of the Blast Furnace" was submitted to the American Institute of Mining Engineers in the autumn of 1904, soon after Mr. Gayley's paper was read, but was held up in the secretary's office for almost a year. It was, however, presented orally at the Washington meeting of the Institute in May, 1905.

It was with great trepidation that I attacked the old theory as so incomplete as to be utterly misleading, expecting to be savagely criticized for my temerity and to see efforts made to riddle the new theory, and it was correspondingly surprising to see it accepted without a single protest by American furnacemen and metallurgists, because it explained Mr. Gayley's results. Thus instead of his facts being used to sustain the new theory, as would surely have been expected, the new theory was quite generally accepted because it sustained Mr. Gayley's facts.

It is proper to say that while the acceptance of the new theory seems as far as one can judge to be quite general in America, there are many indications that it has made little or no impression in Europe, and it seems, as far as I can gather, to have been definitely rejected in Germany.

After the lapse of ten years, during which this theory has been used as a tool for the investigation of many of the problems of the blast furnace, the original presentation seems to me to be as good as anything I can offer now, though it is no more than proper to state that it has been presented in slightly different form by various other furnacemen and metallurgists, some of whom seem to regard it as entirely their own.

The original presentation from the paper above mentioned (Trans. A. I. M. E.) follows.

THE RESULTS OF HEATING AND DRYING THE BLAST

The explanations offered by writers on the blast furnace to account for the economic effect of heating the blast are non-quantitative and therefore inadequate. The following paragraphs, translated from Ledebur', give perhaps the best example:

"When, later, systematic investigations of the influence of the hot blast began to be made, the surprising fact was frequently observed that by heating the blast more fuel could be saved than was necessary for the production of the heat brought in by the hot blast. Moreover, it was very generally observed that the top of the furnace became cooler the more the blast was heated.

"The two phenomena bear a close relationship to each other. The furnace requires, for each kilogram of iron produced, a certain quantity of heat, and the production of this heat, as has been mentioned earlier, is the primary purpose of the combustion of the fuel by the blast. Each kilogram so burnt furnishes a definite quantity of gas which ascends into the furnace.

"But now, if a part of the required heat, instead of being produced by the combustion of carbon, be brought in by the heated blast, the resulting quantity of gas must be as much smaller as corresponds to the saving in fuel; the smaller quantity of gas gives up its heat more quickly and completely to the counter-current of descending solid material than does the larger quantity of gas resulting with the cold blast.

"The heat is accordingly more advantageously utilized in operating with hot blast, and, by this means, a secondary saving in fuel is made. The consequence of this is that the gas leaves the furnace in a cooler condition, and the top temperature falls."

Bell's explanation is not very different and no more satisfactory.

A simple explanation, which affords a basis for quantitative estimates in close accord with the actual facts, is afforded by considering the temperature at which a part of the total heat must be applied.

In the application of heat to the generation of power, it was realized more than a century ago that the temperature of application was of equal importance with the quantity of heat; and it seems remarkable that, in metallurgy, attention is rarely paid to the temperature at which the heat must be applied for the accomplishment of a given purpose, and that quantitative data bearing on this subject are practically unknown.

Calculations of the total quantity of heat imparted to the furnace by the combustion of 1 lb. of carbon, have often been made; and in a few cases calculations have also been made as to the maximum temperatures obtainable under various conditions, but if there have ever been any calculations as to the quantities of heat available at different temperatures, I have never heard of them.

The point of view from which this subject should be considered differs so slightly, but so radically, from the common one, that the distinction is not easy to make clear, but may perhaps be best approached by the conception of a "critical" temperature. It may be said without reservation that for every set of furnace conditions there is a certain critical temperature above which only, certain necessary operations of the process can be carried out. It is not necessary to know what the operations are, and no attempt will be made to enumerate them here, further than to say that they probably comprise the removal of the final traces of oxygen from the ore, the formation and subsequent superheating of the cinder, and the melting, carbonization and superheating of the iron—"superheating" being used in the sense of heating above the point of fusion.

Given the existence of such a critical temperature, it is easy to see that where the heating is done by direct contact with the combustion and its products, as in the bosh of a blast furnace, the only heat available for performing the operations which must take place above the critical temperature is the portion left after deducting the amount necessary to raise the products of combustion to that temperature. Or, to state the proposition in another way, if all the heat developed by combustion passed into the products of combustion, there would be available for the work of the hearth only that portion, the removal of which would suffice to reduce the products of combustion themselves to this critical temperature.

It is obvious that the nearer the critical temperature is to the theoretical temperature of combustion, the smaller will be the quantity of such available heat. If

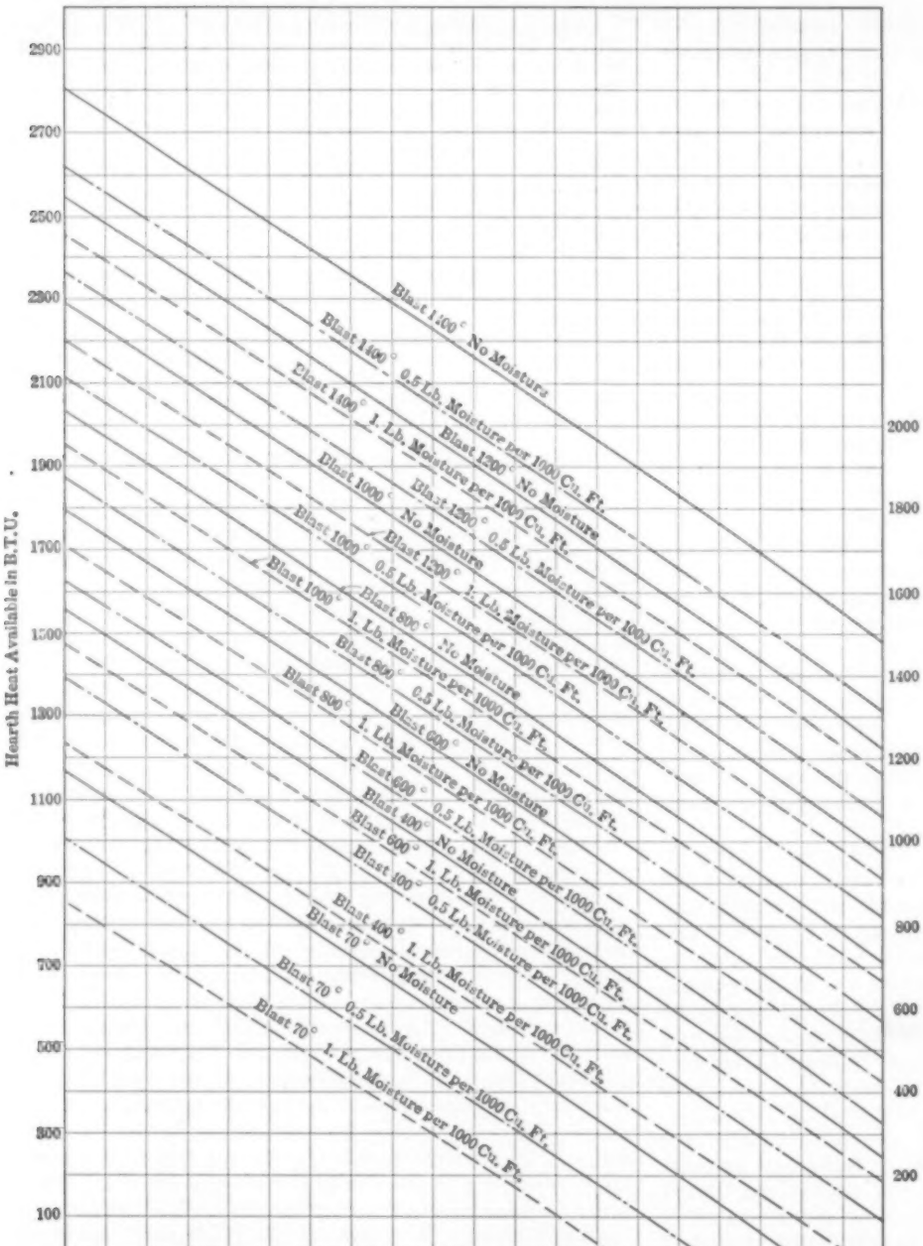

Hearth Heat Available in B.T.U.
Critical Temperature - Fahrenheit
Blast 1400° No Moisture
Blast 1400° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1400° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 1200° No Moisture
Blast 1200° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1200° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 1000° No Moisture
Blast 1000° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 1000° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 800° No Moisture
Blast 800° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 800° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 600° No Moisture
Blast 600° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 600° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 400° No Moisture
Blast 400° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 400° 1. Lb. Moisture per 1000 Cu. Ft.
Blast 70° No Moisture
Blast 70° 0.5 Lb. Moisture per 1000 Cu. Ft.
Blast 70° 1. Lb. Moisture per 1000 Cu. Ft.

FIG. 1—HEARTH HEAT AVAILABLE PER POUND OF COKE, COUNTING 0.85 LB. OF FIXED CARBON ACTUALLY BURNED IN HEARTH, WITH DIFFERENT CRITICAL TEMPERATURES ALSO DIFFERENT BLAST TEMPERATURES AND DIFFERENT MOISTURE CONTENTS IN THE BLAST

the critical temperature is, say, four-fifths of the theoretical combustion-temperature, then the available heat is only one-fifth of the total; and while the other four-fifths are useful for other purposes, they are lost for those under consideration.

The critical temperature varies in the same furnace with varying conditions, but for certain conditions it was determined to be about 2750 deg. Fahr., as a probable average, and results obtained from calculations made on this basis were in such close agreement with the results, that the series was extended to cover other conditions, namely, two other critical temperatures, and varying quantities of moisture in the blast.

Such calculations are extremely simple and involve no uncertain assumptions, the method being as follows:

The combustion receives heat from three sources: the heat of combustion of carbon to CO; the heat brought in by the blast, and the heat brought in by the fuel. The latter may reasonably be assumed to be brought up to the critical temperature by the gas leaving the bosh, as the heat exchange is a true counter-current one, and the contact is intimate.

The heat brought in by the coke is therefore $2750 \times 0.21 = 577.5$ B.t.u., the heat of combustion of 0.9 lb. of carbon is $4450 \times 0.9 = 4005$ B.t.u., and the heat brought in by the air at 70 deg. Fahr. (cold blast) is $5.22 \times 0.2375 \times 70 = 86.8$ B.t.u., a total of 4669.3 B.t.u.

The products of combustion are 4.02 lb. of nitrogen and 2.1 lb. of CO; to heat these to 2750 deg. requires respectively $4.02 \times 0.2438 \times 2750 = 2695.2$, and $2.1 \times 0.2479 \times 2750 = 1431.6$ B.t.u., a total of 4126.8 B.t.u., which deducted from 4669.3 leaves 542.5 as the available heat above 2750 deg.

Now assume the blast to be heated to 1000 deg.; the heat brought in by the blast becomes 1241.8 B.t.u., or 1155 B.t.u. more than before; the other items of heat brought in remain the same, as do those of heat removed by the products of combustion; consequently, the available heat is increased by this amount, which is a little more than twice the original amount, making the available heat in this case 1697.5 B.t.u., or more than three times that in the previous case.

A series of calculations were made on this basis for different blast-temperatures, and also for different critical temperatures; these are given in graphic form in Fig. 1.

It is perfectly obvious that the higher the critical temperature the less the available heat will be for a given blast-temperature, and vice versa.

The modification introduced by variable moisture content in the blast is not quite so simple, but not in the least complicated.

By way of preliminary it may be explained that the unit of moisture in the blast here adopted is 1 lb. per 1000 cu. ft. of air, since the latter is the unit of blast measurement. There being 7000 grains in a pound the commonly-used unit of grains per cubic foot may be reduced to that here used by simply dividing by 7.

(*To be continued in issue of Nov.* 1)

Cryolite.—No cryolite is produced in the United States, the entire supply used in this country being imported from Ivigtut, an Eskimo hamlet on the southern coast of Greenland, free of duty.

Metallurgy at the International Engineering Congress—II

San Francisco, September 20 to 25, 1915

In our last issue accounts were given of the papers and discussions on iron and steel and on copper. In the following we will first report two papers on copper omitted in our last issue on account of limitations of space and then give an account of the symposia on gold and silver, zinc, lead, and fuels.

Copper

(*Concluded from page* 662)

The Metallography of Copper was the subject of a paper by Prof. WILLIAM CAMPBELL of Columbia University. The author discusses the effect of copper oxide on copper and the effect of cold work and hot work on the structure of copper.

To show the effect of copper oxide on copper the author reviews the work of Heyn and Slade and Farrow. The freezing point of copper, 1084 deg. C., is depressed by the addition of Cu_2O, progressing until we reach a minimum of 1065 deg. C. and 3.5 per cent Cu_2O. A further increase in Cu_2O raises the freezing point of the mixture.

The effect of cold work on the structure of copper is to draw out the grains of metal, and the greater the reduction the more the grains are drawn out. The reason for the increase in strength and decrease in ductility is matter of dispute. The "amorphous theory" has gained support. It holds that (a) polishing produces a film of amorphous metal as the surface; (b) when a metal is strained, the slip-lines and slip-bands are covered with a film of amorphous metal, which is less dense and much harder than the crystalline variety; and (c) where the crystals of a metal meet, thin films of residual liquid metal will remain under circumstances which render them incapable of crystallizing, so that they form films of amorphous metal as an intercrystalline cement.

In studying the effect of hot work, the first thing noted was that the Cu_2O of the eutectic was drawn out into long strings of rounded globules. The structure, after different degrees of reduction, resembled that of annealed metal. While the grains became progressively smaller they showed no elongation because the heat was sufficient to cause a rearrangement of the grain.

According to Faust, the crystallites in electrolytic copper arrange themselves parallel to the lines of the current. Electrolytic copper, like worked copper, develops twinning planes when annealed, indicating the presence of internal stress.

Boronized Cast Copper was the subject of a paper by Dr. E. WEINTRAUB of the General Electric Co., Lynn, Mass. The author discusses the theory and practice of the use of "boroflux" for producing cast copper of good mechanical properties and high electrical conductivity. Numerous references to the same subject may be found in the files of this journal.

Boroflux is defined as a material containing boron in a state of oxidation below that of boric anhydride. Such a material takes up oxygen and reduces oxygen-containing compounds. In this reaction the boroflux is transformed into boric anhydride which, being fluid at the temperature of the reaction, comes to the top of the metal, carrying in solution metallic oxides, particularly cuprous oxide. Boron suboxide and boron carbide are generally used, the suboxide being preferable. Three-quarters of one per cent is usually added. An average conductivity of over 90 per cent is regularly obtained. The efficiency of boroflux in deoxidizing copper that has been remelted a number of times is shown in the following table. A.B. indicates the average number of bends; R. indicates the resistance offered by test bar to the bend, given in percentage, assuming virgin copper to be 100 per cent.

	A. B.	R.
Virgin metal	1515	100%
First heat	850	97
Fourth heat	334	96
Boron suboxide	2007	103

The Coolidge tube has been used for making x-ray photographs of metal that has been treated with boroflux, in comparison with untreated metal. The photographs show the porosity of ordinary cast copper and the solidity of copper cast with boroflux.

Gold and Silver

The symposium on gold and silver, which had been prepared and edited by C. W. MERRILL, was the subject of discussion in the session of the morning of Friday, Sept. 24, CHARLES BUTTERS presiding.

A Coarse Crushing Plant of 1000 tons capacity was the subject of a paper by G. O. BRADLEY. The author stated that the equipment and arrangement of crushing plants is now receiving the same attention which was formerly devoted only to other parts of the reduction works. Manufacturers are now producing complete lines of machines suitable for special type of ores. The author outlined the design of a plant for dry crushing a thousand tons of ore of average hardness to ¼ in. in size, using electric power, concrete-steel construction, gyratories, rolls and automatic balanced skips, instead of bucket elevators, giving an estimate of costs and detailed drawings.

Mr. Bradley's paper developed some discussion on the relative merits and the proper use of jaw and gyratory crushers. Prof. Robert H. Richards stated that in his opinion gyratory crushers were specially adapted for large central plants and jaw crushers for secondary work. But the recent construction of the Traylor jaw cushers, 5 x 7 ft., may necessitate a change of this opinion. Crushing practice is now in a period of change.

Crushing and Grinding.—The trend of recent practice in crushing and grinding for cyanidation is outlined in this paper by L. D. MILLS and M. H. KURYLA. Large-scale operations, such as described in the foregoing paper by G. O. Bradley, are in a class by themselves and not adapted to the ordinary cyanide plant. Primary crushing is usually done in two stages: first a jaw crusher breaking from run-of-mine to 6 in., and then cone crushers to reduce this material to 2 in. The Symons disc crusher is a recent machine which is giving good results in crushing from 4 or 6 in. down to 1 or 2 in. This machine is good on hard, brittle ores, but not adapted to wet, sticky ores. Undersize must be eliminated from the feed. Typical costs of coarse crushing and conveying are given below:

Goldfield Consolidated, Nev., crushing and conveying	$0.046
Belmont Milling Company, Nev., crushing and conveying	0.068
Commonwealth Mine, Arizona, crushing and conveying	0.079
Hollinger Gold Mines, Porcupine, crushing and conveying	0.113

Fine crushing or coarse grinding covers reduction from 1½ or 2 in. to 0.25-in. aperture. The term to be used depends on whether the energy is applied by impact or attrition or both.

The gravity stamp crushing by impact is probably used in 95 per cent of the cyanide plants of the world. In spite of its unquestioned disadvantages, it continues in favor. There is a tendency in American and Canadian practice to adopt the ball mill, and it is the authors' belief that few, if any, new stamp mills will be built on the American continent.

The economic limit of battery-screen aperture in modern plants is considered to lie between 0.15 to 0.4 in. This statement applies either to American and Mexican all-sliming practice, 70 per cent or more through 200-mesh, or to Rand practice, 95 per cent through 65-mesh.

Stamp mill practice has reached its highest development in South Africa. The Nissen single stamp has been received with some favor there, showing one-third greater capacity, per pound of falling weight, and an equal gain in efficiency over the ordinary gravity stamp. Of the six new mills built on the Rand since competitive trials were made, however, only one proposes to adopt the Nissen stamp. In modern Rand plants the

Stamp Milling Data

Plant	Tons Milled 24 Hr.	Number of Stamps	Running Weight	Discharge Aperture	Hp.-Hr. P. T. Milled	Stamping Cost, Cts. P. T. Milled	Sizing	
							% −100 (0.0055 In.)	% −200 (0.0029 In.)
Mexico Silver Mill	1000	60	1450	0.371	4.8	10.0	....	14.0
Nipissing	245	40	1450	0.334	12.1	23.8	20.3	16.7
Belmont	500	60	1200	0.131	7.2	20.7	28.3	19.5
Silver Peak	500	120	1050	0.023	13.8	31.4	54.0	40.6
Homestake	4500	1020	850	0.022	11.0	20.4	80.0	60.0
Hollinger	585	60	1400	0.263	8.6	16.0	....	15.0
Porcupine Crown	150	20	1000	0.250	6.0	14.0	....	15.0
Liberty Bell	485	80	750	0.041	7.8	19.1	54.0	46.0

cost of stamping does not exceed 20 cents per ton; the average for the district in 1913 was 29.3 cents for thirty of the large plants.

Tube-mills have now been universally adopted for final grinding to a finished product. Classification for the elimination of finished material from the tube-mill discharge is a matter vital to the efficiency of the mill and has received close attention. Cone classifiers with diaphragms a few inches above the apex are preferred on the Rand where coarse grinding is employed. In America the Dorr, Akins, Ovoca and Esperanza classifiers are used, the tube-mills being in closed circuit.

Tube-Milling Data

Plant	Tons Milled 24 Hr.	No. Tubes	Dimensions of Tubes	Hp.-Hr. P. T. Milled	Cost P. T. Milled	Sizing Final Product	
						% −100 (0.0055 In.)	% −200 (0.0029 In.)
		6	5 ft. x 16 ft.				
Mexico Silver Mill	1000	6	5 ft. x 20 ft.	10.8	22.0	98.0	75.0
Nipissing	245	4	6 ft. x 20 ft.	44.6	50.0	100.0	100.0
Belmont	500	7	5 ft. x 18 ft.	16.8	40.9	99.0	72.3
Silver Peak	500	1	5 ft. x 18 ft.	2.4	2.6	64.0	50.0
		2	5 ft. x 14 ft.				
Homestake	4500	2	5 ft. x 18 ft.	0.5	1.2	87.0	66.0
Hollinger	585	6	5 ft. x 20 ft.	16.0	18.8	100.0	90.0
		1	5 ft. x 16 ft.				
Porcupine Crown	150	1	4 ft. x 20 ft.	5.7	36.0	100.0	90.0
Liberty Bell	485	3	5 ft. x 22 ft.	4.3	7.7	87.0	73.4

The authors note that the efficiency of the closed circuit has been questioned, but add that the contentions against it are not borne out in practice. As to moisture in tube-mill feed, 38 to 40 per cent has been generally accepted, and is probably correct for mills discharging within 6 in. of the central axis; but for mills with peripheral discharge, higher moistures will be found advisable. The proportion of tube-mill capacity to stamp capacity has been increased, and costs have been lowered as more work has been thrown on the tube-mill. It is possible that ball and tube-mills in series may supplant the stamp. Various substitutes for pebbles are being investigated, such as hollow cast iron or steel balls, and special polyhedron shapes. The Marathon or rod mill also has been tested with favorable results. Tube-milling costs in the newer plants on the Rand are about equal to stamp-milling costs; 18 to 20 cents per ton milled.

The use of stamps, Chilean mills and tube mills for stage crushing and grinding at the Goldfield Consolidated is unusual, but productive of low cost of operation. Stamps weigh 1050 lb., crushing through 4-mesh screen; 6-ft. Chilean mills have 30-mesh screens; tube-mills are 5 ft. by 22 ft. Following are costs per ton milled:

	Stamps		Chilean Mills		Tube Mills	
Labor	$0.039		$0.018		$0.014	
Supplies	0.041		0.041		0.065	
Power (232 hp.)	0.054	(210 hp.)	0.047	(357 hp.)	0.087	
	$0.134		$0.106		$0.166	

Power consumed by stamps, Chilean mills and tube mills ..... 22.5 hp.-hr. per ton milled
Total combined cost for stamps, Chilean mills and tube mills ..$0.406 per ton milled

Chilean mills are used at the Portland mill, Cripple Creek, for final grinding where a fine product is not required. Six-ft. Akron Chilean mills run at 36 to 41 r.p.m., using 2.5 to 3 tons of solution per ton of ore. Steel consumption per ton of ore ground is 0.797 lb. gross and 0.692 lb. net. Power consumption per ton of ore in coarse-crushing department is 1.86 hp.-hr. and in Chilean mills, 13.26 hp.-hr., or a total of 15.12 hp.-hr. Following are cost data.

	Coarse Crushing, per Ton	Chilean Mills, per Ton	Total, per Ton
Power (at 0.842c. hp.-hr.)	$0.0199	$0.1118	$0.1317
Labor (operation)	0.0318	0.0179	0.0497
Labor (repairs)	0.0103	0.0039	0.0142
Supplies	0.0284	0.0482	0.0766
Total	$0.0904	$0.1818	$0.2722

Dry crushing in ball mills is still retained at Kalgoorlie, the data for No. 5 and No. 8 mills, respectively, being as follows: Size, 7 ft. 6 in. in diameter by 3 ft. 10 in. long, and 8 ft. 10 in. by 4 ft. 6 in.; screen areas, 70 and 100 sq. ft.; speeds, 25 and 23 r.p.m.; power consumption, 25 and 60 hp.; capacities, 40 and 95 tons per day, the feed being about 2½ in. and the discharge through 28-mesh screen containing from 40 to 50 per cent minus 200-mesh; steel consumption per ton milled varies from 0.4 to 0.7 lb.; average cost of ball-milling, $0.50 per ton milled.

Wet crushing ball mills are coming into favor with excellent results. They run smoothly and are free from the noise produced by stamps. Recent tests on an 8-ft. Marcy mill showed that when operated in closed circuit on 4-in. maximum feed, the finished product may be kept under 48-mesh if desired. Steel consumption was 0.75 lb. per ton crushed, and power consumption about 12 hp.-hr. per ton.

Griffin mills and grinding pans, once widely used, are now rarely installed in new plants.

In the discussion of the paper Mr. Charles Butters predicted that steel balls would displace pebbles for tube milling, as they would permit the use of shorter tubes with smaller diameter, running at a higher speed, with a consequent reduction in first cost and in operating cost. One pound of steel balls is equivalent to three to five pounds of pebbles.

Solution of Gold and Silver.—In this paper by M. H. KURYLA, on the solubility of gold and silver in cyanide solutions and the methods of treating ores to effect the dissolution of those metals, the author covers an extensive subject in small compass. The paper is already so condensed that abstracting is difficult. An effort is made to give typical examples and costs of treatment from different parts of the world. On the chemical side it is pointed out that the classical equation of Elsner,

$$2Au + 4KCN + O + H_2O = 2KAu(CN)_2 + 2KOH,$$

so generally accepted as representing the final reaction, is inadequate as a guide to the consumption of cyanide in the treatment of complex ores. The equation calls for 1.51 units of gold or 0.83 units of silver per unit of KCN. This relation is closely approximated in the treatment of many silver ores, but with gold ores a consumption of 20 of KCN to 1 of gold is considered satisfactory and 40 to 1 is more common.

The strength of cyanide solution for silver ores will probably average 4 lb. KCN per ton, and for gold ores, 1.5 lb. Average chemical and mechanical loss of cyanide will average 2 lb. for silver and ¾ lb. for gold ores. Sand leaching plants have contacts of from four to seven days, while the time of contact for slime in gold ores is about 8 hr. and in silver ores 48 hr. Heating solutions has been of benefit in silver ores, increasing dissolution by an ounce or two at a cost of from 10 to 25 cents per ton.

Amalgamation is an important accessory process to cyanidation, particularly in recovery of such coarse gold as may retard or escape dissolution in cyanide. As practised at the average plant it costs between 5 and 10 cents per ton, and the plate area is about 2 sq. ft. per ton milled. On the Rand the plate area ranges from 0.25 to 2 sq. ft. per ton milled, and the mercury consumption about 0.1 oz. At the Homestake, with inside and outside amalgamation, the plate area is about 11 sq. ft. per ton milled, with a mercury loss of 0.13 oz.

Concentration is another accessory process, practised for (a) shipment of high-grade concentrates to smelters; (b) recovery of lower grade concentrates for local cyanidation; and (c) removal of concentrates for finer grinding and subsequent return to the mill pulp. The cost ranges from 5 to 15 cents per ton, averaging perhaps 10 cents. The following table gives condensed data on cyanidation of concentrates. The details of the processes have been given in the technical press.

CYANIDATION OF CONCENTRATES

Plant	Daily Production in Tons	Assay Ozs. per Ton		% Extraction		Cons. p. c. Concentrates	Cost per Ton of Concts.						
		Au.	Ag.	Au.	Ag.	KCN lbs.	Grinding	Roasting	Dissolution	Acid Treatment	Filtering	Precip. and Refining	Total
A—Goldfield Cons., Nev.	55	6.58		98.53		7.	0.33	0.82	2.34	0.77	0.30	0.18	$5.68
B—Alaska Treadwell	75	2.92		96.5		2.3	0.57		0.78		0.22	0.81	2.81
C—Esperansa Mexico	1	22.68	54.2	99.4	95.8	6.0							4.85
D—Waihi, N. Z.	17	5.6	63.3	96.3	93.5	20.0							6.25
E—Geldenhuis Deep, Transvaal		16.0		98.75		3.3	3.65		2.67				6.32
F—Oriental Cons., Korea		2.2		93									2.87

Roasting is practised prior to cyanidation when the ore contains tellurium, arsenic or antimony, with which the gold may be intimately associated, either physically or chemically, the object being to liberate the gold for contact with cyanide. This is practised most extensively at Kalgoorlie, and to some extent on Cripple Creek telluride ores and on the graphitic ores of the Ashanti Goldfields. It is also practised on the concentrates at Goldfield, Nev. At Kalgoorlie the cost is about 65 cents per ton when using Merton or Edwards furnaces. Hearth area per ton of ore roasted in 24 hr. varies from 17 to 29 sq. ft. The cost of roasting Cripple Creek ore at the Portland mill in Holthoff and Pearce furnaces is 62.85 cents per ton. Chloridizing-roasting in the Holt-Dern furnace costs 51.5 cents per ton, including 35 cents for salt and 4.6 cents for coal dust.

Wet desulphurizing is accomplished at the Nipissing mill by grinding a complex arsenic-antimony-silver ore in 0.25 per cent NaOH solution and tube-milling with aluminium ingots and agitated in tanks containing aluminium sheets. The cost amounts to 48 cents per ton.

The standard systems of cyanidation, in order of prevalence, are slime agitation, sand leaching and filter slime treatment.

For slime agitation the ore is first thickened to a dilution of 1.5. Thickening is done in various forms of tanks, but the Dorr continuous thickener is favored. An average of 6 sq. ft. of settling area is allowed per ton of granular slime, and 10 to 15 ft. for flocculent material. Capacity may be greatly increased by the use of submerged trays in the same tank. Power requirement of a 30 ft. by 12 ft. Dorr thickener running at 1/5 r.p.m. is ¼ hp., and the operating cost about 1 cent per ton.

In agitation the trend is toward continuous operation. Four types of agitators are in use, one of which, the pump transfer system, is used mainly on the quick settling slime of the Rand. The other three systems are the mechanical, pneumatic and a combination of the two. The mechanical type has paddle-arm stirrers; the pneumatic uses compressed air in a central air-lift, as in the Brown or Pachuca; the combination uses both mechanical and pneumatic agitation, as in the Dorr.

COMPARATIVE AGITATOR DATA

M.—Bottom Drive Mechanical. Sp. Grav. of Pulp = 1.326 (L:S = 1.5:1)
P.—Pachuca. Power at $5.00 per hp. per month.
D.—Dorr. Labor at $3.00 per 8-hr. shift.

Type	Size, Feet	Capacity, Dry Tons of Slime	Total Erected Cost	Erected Cost per Ton of Capacity	Power per 100 Tons of Slime	Total Operating and Repair Cost per Ton of Slime per 24 Hrs.—500 Ton Plant
M	30x12	134	$2395.00	$17.87	D—3.0 hp.	D—1.8 cents
D	30x12	134	2510.00	18.73	M— .2 hp.	P—2.3 cents
P	15x45	102	1935.00	18.97	P—6.9 hp.	M—2.4 cents

Agitator Requisites	Violence of Agitation	Total Operating Cost per Ton	Regulation of Amount of Air for Aeration	Freedom from Choking or Settling	Ease of Starting After Shut-down	Adaptability to			Operating Simplicity	Minimum Loss in Mill Height
						Varying Pulp Conditions	Continuous System of Agitation	Selective Agitation		
In order of preference	P D M	D P M	M D P	D P M	P D M	P D M	D P M	D P M	P D M	D M P

The following figures on the cost of dissolution by slime agitation are merely numerical averages of compilations from representative plants in various parts of the world. The cost of dissolution includes thickening, agitating, proportionate pumping, supervision, cyanide, lime and lead salts.

	Cost of Dissolution	Cost of Filtration or Decantation Precip. and Refining	Total
Average gold ore	$0.29	$0.25	$0.54
Average silver ore	0.83	0.42	1.25

Sand leaching is practised most extensively on the Rand. Cost figures from 10 Rand plants in 1912, show the following averages:

Total cost of sand treatment per ton of sand (including classification, collecting, treating, precipitating, refining and residue disposal), ranging from 37 to 45 cents, average	39.8 cents
Average extraction on $3.17 sand heads	79.8%
Average extraction in recent sand plants	89.5%

At the Homestake the cost for sand leaching is 17.8 cents per ton; at the Pittsburgh Silver Peak, 23.5 cents. Itemized costs for the Rand and Homestake are:

Cost of Sand Treatment per Ton of Sand

Rand		Homestake	
Labor	6.54 cents	Superintendence	1.06 cents
Assaying, sampling	0.32	Assaying	0.48
Lime	0.56	Neutralization	1.54
Transferring, discharging	8.62	Transportation	0.17
Cyanide	7.23	Classification	1.18
Precipitation	1.56	Treatment	8.59
Zinc shavings	1.28	Precipitating and pumping solutions	1.18
Clean-up, smelting	2.92	Refining	0.38
Sodium bisulphate	0.94	Heating	0.51
Miscellaneous supplies	2.30	Miscellaneous	0.81
Water	1.60	Repairs	1.88
Power and lights	6.48		
Miscellaneous	0.59		
Total	40.94 cents	Total	17.78 cents

Direct treatment of slime in filters is practised at the Homestake and at the Pittsburgh Silver Peak. The cost at the former is 18.38 cents per ton and at the latter 26.3 cents.

In the discussion which followed, J. C. Clennel mentioned the bad effect of an oxidizing roast on silver extraction. C. W. Merrill cited a case in which after the roast a 15 per cent lower extraction was obtained than on raw ore. G. H. Clevenger mentioned the same effect was produced by natural surface oxidations of silver ores, also containing manganese dioxide. Charles Butters spoke of the importance of the dilution of pulp on silver extraction. He is now working on new problems of cyaniding flotation concentrates.

Filtration of Slime.—In this paper by L. D. Mills, all processes for separating and recovering valuable metal-bearing solution from slime are considered. This is one of the most vital points in cyanidation. The various methods considered are: Thickening, vacuum filtration, pressure filtration, continuous decantation and intermittent decantation.

The use of the Dorr continuous thickener has become almost universal. Discharges as low as 33 per cent and up to 60 per cent moisture can be obtained, varying with the nature of the slime. On the Rand, with colored labor at $0.75 or less per day and power at $5.50 per hp.-month, it is still found economical to retain intermittent settlers. The cost of thickening will vary from $0.005 to $0.02 per ton of ore milled, depending on local conditions and scale of operations.

Among vacuum filters, the author considers the Butters by far the most widely used. Others are the Moore, Oliver, Portland and Ridgeway. Average cost of operating Butters filters on the Rand is given as $0.065 per ton filtered. The caking effluent is worth $2 per ton, and the dissolved loss amounts to $0.05 or less. At the Goldfield Consolidated, the cost of operating a Butters filters is $0.05 per ton. Dissolved loss is $0.06. Other Butters operating costs are:

McNamara, Tonopah	150 tons silver,	$0.237 per ton filtered
Montana-Tonopah, Tonopah	146 tons silver,	0.230 per ton filtered
Loretto, Pachuca	700 tons silver,	0.07 per ton filtered
Flores, Guanajuato	160 tons silver,	0.06 per ton filtered
Dos Estrellas, El Oro	750 tons gold,	0.075 per ton filtered

A 1000-ton filter at the Victoria mill, Australia, has an operating cost of $0.0996 per ton filtered. The caking effluent averages $4.60 gold and 1.72 oz. silver, with dissolved loss at $0.048 gold and 0.02 oz. silver. Other Moore filter costs are:

Hollinger, Porcupine	600 tons gold,	$0.103 per ton filtered
Liberty Bell, Colorado	430 tons gold and silver,	0.099 per tonfiltered
La Blanca, Pachuca	300 tons silver,	0.105 per ton filtered
San Rafael, Pachuca	400 tons silver,	0.110 per ton filtered

Note.—These costs do not include royalty.

The Oliver and Portland are revolving-drum continuous filters. Operating cost of an Oliver filter at the Mexican mill on the Comstock is given as $0.072; dissolved loss, $0.09, largely in silver. At the Portland mill, the operating cost of Portland filters is $0.08 per ton filtered; dissolved loss, $0.07, mainly in gold.

Among pressure filters the author discusses the Dehne, Merrill, Kelly and Burt.

Dehne presses were used in the early days of cyaniding, particularly in Africa and Australia. They are adapted to treatment of granular or roasted slime; with amorphous slime the cakes must be thin and the washing is erratic. The average cost of operation in Australia may be taken as $0.25 per ton filtered, with $0.10 per ton additional for residue disposal.

The Merrill automatic sluicing filter press combines the washing efficiency of the plate-and-frame press with convenient wet discharge of cake. When the ore is comparatively granular the press is filled solid full; when amorphous material is present, it is advisable to fill the chambers not quite full. The capital cost of the filter is high, but it has an unusually high washing efficiency and low operating cost. At the Homestake the cost is $0.028 per ton, including labor, power and supplies.

The Kelly enclosed-leaf pressure filter shows an operating cost of $0.25 per ton at the 250-ton plant of the Tigre Mining Co., in Sonora.

The Burt revolving filter is restricted in use to granular slime. At El Oro operating cost was $0.049 per ton. The washing efficiency is stated to be 98 per cent.

Continuous counter-current decantation with Dorr thickeners is becoming a popular process, especially for small plants. The mechanical loss of cyanide is one of the factors that limits its use without filters. Actual operating cost is very low; at the Porcupine-Crown the cost of dissolution and counter-current washing approximates $0.30 per ton.

The author concludes that the handling of slime has reached a development where no further radical changes are to be expected. The mechanics of the various operations will be modified to suit special conditions, and there is always a possibility of reducing capital cost.

In the discussion which followed, Mr. Butters disagreed with the author's conclusion that no more radical changes in slime treatment may be expected. Mr. Butters anticipates that other forces than gravity may be

advantageously employed in the future for settling slime, such as electrical and centrifugal forces.

Precipitation of Cyanide Solutions.—The author of this paper, G. H. CLEVENGER, has gone thoroughly into the history and present status of the processes of precipitating precious metals from cyanide solutions.

CLASSIFICATION OF VARIOUS METHODS OF PRECIPITATION, USED AND PROPOSED

ELECTROLYTIC	(a) Iron anode; lead cathode; low current density; adherent deposit.			
	(b) Peroxidized lead anode; tin plate cathode; high current density; non-adherent deposit.			
	(c) Peroxidized lead anode; lead plate cathode; high current density; adherent deposit.			
	(d) Indirect electrolytic processes have only been investigated experimentally.			
CHEMICAL	Gaseous	Only example; possibly occluded gases in charcoal.		
	Liquid	Sodium sulphide (proposal for precipitating silver cuprous salts in acid solution).		
	Solid	Non-metallic	Charcoal	
		Metallic	Sodium	In form of amalgam, generally produced by electrolysis
			Aluminum	Shavings Dust
			Zinc	Discs Shavings Dust

Electrolytic precipitation by the Siemens-Halske process was developed in South Africa to cope with low-grade solutions resulting from slime treatment. These solutions were not successfully precipitated on zinc. Later the introduction of the lead couple and a drip of strong solution made zinc precipitation satisfactory, and electrolytic precipitation declined and finally was abandoned. The latter process was used also by Charles Butters in San Salvador, Mexico and Nevada, but finally abandoned as zinc precipitation became better understood and improved. The following table gives the essential features of the electrolytic precipitation as practised in the past at various plants:

Process	Location	Number of Plants	Anode	Cathode	Current Density per Sq. Ft. Anode Amperes	Voltage	Metals in Solution	Remarks
Siemens-Halske	Rand, South Africa	20	Iron	Lead foil	0.03 to 0.06	4 to 8	Gold	Used alone
Butters-Andreoli	Minas Prietas, Mexico	1	Peroxidized lead	Tin plate	0.30 to 0.55		Silver, copper, gold	Used alone
Butters-Andreoli	San Sebastian, Salvador	1	Peroxidized lead	Lead plate	1.00 to 1.20	3 to 3.5	Copper, gold, zinc	Followed by zinc shavings
Butters-Andreoli	Virginia City, Nevada	1	Peroxidized lead	Aluminium plate	0.25	2.87	Silver, copper, gold, zinc	Followed by zinc shavings
Butters-Andreoli	El Rayo, Mexico	1	Peroxidized lead	Copper foil	1.20		Silver, copper, gold, zinc	Preceded by zinc dust

Charcoal precipitation is briefly discussed and the principles of aluminium precipitation are given. This latter process has been described in this journal, August, 1914, page 511.

COST OF ZINC SHAVING PRECIPITATION

Name of Plant	Type of Ore	Size of Compartments, In.	Cu. Ft. of Zinc per Ton of Solution Precipitated per 24 Hr.
San Rafael, Pachuca, Mexico	Silver-gold	33x33x30	
Loreto, Pachuca, Mexico	Silver-gold	36x48x30	0.75
Dos Estrellas, El Oro, Mexico	Silver-gold	30x30x24	0.65
El Oro Mining & Railway, El Oro, Mexico	Gold-silver	36x48x24	
Guanajuato Consolidated, Guanajuato, Mexico	Silver-gold	36x48x18	0.40
Guanajuato Reduction & Mines Co., Guanajuato, Mexico	Silver-gold	48x48x30	1.06
Divisadero, San Salvador, Central America	Silver-gold	24x36x18	0.54–0.81
Golden Cycle, Colorado Springs, U. S. A.	Gold	48x24x24	0.56
Tonopah Extension, Tonopah, Nev., U. S. A.	Silver-gold	30x34x26 36x34x30	0.93

Zinc precipitation is discussed under the heads of zinc shavings, wafers and dust. Numerous illustrations are given to show the manner of applying these methods, and considerable space is devoted to the preparation of zinc shavings. The Merrill zinc-dust process is described in detail.

Data on zinc-dust precipitation at the Homestake covering a period of one month are given as follows:

Plant	Heads	Tails	Pounds Zinc Dust per Ton of Solution	Cost of Precipitation per Ton of Ore Treated
No. 1 sand	$2.94	$0.018	0.173	$0.0123
No. 2 sand	2.77	0.034	0.174	0.0109
Slime	1.19	0.028	0.160	0.0165
Average on whole ore	1.87	0.026	0.165	

In refining, preliminary acid treatment of the precipitate has been found unnecessary in most cases where silver predominates, but is still adhered to in the majority of cases for gold precipitate.

The oil-fired tilting-crucible melting furnace has now largely replaced the earlier types of stationary-crucible furnaces, thus making the melting operation much less laborious, as well as considerably reducing its cost.

The Tavener method of refining, involving the melting of the precipitate in a small reverberatory furnace with various fluxes and lead, followed by cupellation, is still in general use in South Africa, but has not gained ground in this country.

The Homestake method of refining, involving acid treatment and briquetting with lead flux, followed by melting and cupellation in the ordinary English cupel furnace, as well as the treating of all the by-products in a small blast furnace, is used by a few American plants.

The melting of the precipitate, briquetted with the proper fluxes, in a small blast furnace, followed by cupellation of the lead, has been found of advantage when dealing with a large volume of low-grade gold precipitate. Losses from dusting, which might appear to be the chief objection to this method of melting, are claimed to be insignificant when a proper flux system is provided. This method of melting is more economical than either the Tavener or Homestake practice.

The most simple and satisfactory method of converting the high-grade precipitate which is obtained, by proper manipulation, from ores in which silver predominates is to melt the precipitate directly, with the minimum proportion of flux, in the tilting type of furnace.

In the discussion of this paper E. H. Simonds referred to the precipitation of low-strength cyanide solutions. He said there was no difficulty if both solution and zinc are perfectly clean. Mr. Butters said that aluminium dust is useful for silver solutions, but offers no advantage for gold.

Zinc

In the Friday afternoon session, in which E. B. BRADEN presided, the symposium on the metallurgy of zinc, arranged and edited by WALTER R. INGALLS, was first taken up.

Some main points in the economics of the metallurgy of zinc was the subject of a paper by WALTER R. INGALLS. The effect of the European war will be to produce even more radical changes in the zinc industry than were in progress when the war began.

The introduction of the Wilfley table in 1896 was an historic event in the zinc industry, for it made possible a better separation of the mixed ores requiring fine grinding. Another important step in the metallurgy of mixed ores was the introduction of the Wetherill system of magnetic concentration, followed by Blake's system of electrostatic concentration. The climax has been reached in the successful use of flotation at Broken Hill.

The development at Broken Hill had many important consequences: it standardized smelting practice in Belgium and Germany; compelled those smelters to go on a zinc-lead basis; showed that mixed ores could be profitable, and resulted in similar development elsewhere in the world.

During the last 50 years there have been three types of zinc smelting (the earlier English and Carinthian processes having disappeared), which are known as the Silesian, Belgo-Silesian, and Belgian. In recent years, the Belgo-Silesian method has become known as the Rhenish, and this has shown a strong tendency to displace the Belgian process in Belgium and an even stronger tendency to displace the Silesian process in Silesia. The reasons for this are discussed in the metallurgical treatises, of which zinc smelting has recently acquired a rich literature. They may be summarized as a superior economy, as compared with the Belgian furnace; and, in Silesia, a change in the character of the ore which causes this method to be better adapted than the Silesian furnace. In the United States, the method of smelting is essentially the Belgian, which has been modified to conform to peculiar conditions.

Another basic factor in the zinc industry which is causing radical change is the manufacture of sulphuric acid from the roasting of blende. This has long been practised in Europe, and is now coming into vogue in America. Every smelter of blende east of the Mississippi River is now making acid.

The author sketches briefly a comparison of European and American practice, and gives the economic reasons for the differences. The following figures are offered as broad generalizations to show the differences in the art as practised here and abroad. They mean that the Europeans, with the aid of better furnaces and superior technical direction, are able to smelt more refractory ores and yet extract a higher proportion of the valuable metals. Such economies as America has effected have been chiefly in the handling of material, which, in zinc smelting, is a relatively small part of the process.

"Per ton of raw sulphide ore, the American smelter uses about 2 to 2½ tons of coal and two or three man-days of labor; and extracts about 84 to 88 per cent of the zinc that is in his ore; if he treats lead-bearing ore, he may recover 50 to 60 per cent of the lead.

"The European smelter uses about 1¼ to 1¾ tons of coal and 3 to 3½ man-days of labor; and extracts 88 to 90 per cent of the zinc that is in his ore, and about 50 to 70 per cent of the lead."

The author concludes with a reference to certain misconceptions respecting the status of zinc smelting, as follows:

"The art of zinc smelting is far from being at a standstill. When we find 1000 kg. of ore requiring 1000 calories of heat being distilled with 1100 kg. of coal equivalent to 8000 calories, as is done in the best practice, we are observing a thermal efficiency of 12½ per cent, which compares favorably with good steam practice. When we find a ton of ore being smelted with 2½ man-days of labor, and consider that we are dealing with a concentrated product, and reflect that the total weight of material handled is relatively small and that the work on it from step to step is often more cheaply done by a man than by a machine, we do not feel unduly mortified by our results. Nor does the extraction of only 85 or 90 per cent of the zinc content of the ore shame us very much when we reflect upon the peculiar and troublesome metallurgical properties of zinc.

"Electric zinc smelting, which has engaged a good deal of attention during the last fifteen years, is metallurgically of the same nature as ordinary smelting; the main difference is that, in one case, the zinc is distilled by the heat of the elecric arc or the heat of electric resistance; while, in the other case, it is done by the combustion of coal. So far, electric smelting has become an art only in Sweden and Norway, where several thousands of tons of spelter are annually produced by this method. The smelters in Sweden and Norway enjoy very cheap power, whereby they have been able to overcome, or at least meet, the main obstacle that has heretofore prevented electric smelting from becoming a commercial art elsewhere."

Development of Zinc Smelting in the United States.—In this paper GEORGE C. STONE directs attention to the tremendous increase in spelter production during the last thirty years, and the fact that more than half of it has been the output of the United States. The first spelter produced in this country was made by the government in 1838 from ore from Franklin Furnace, N. J., and was used for making brass for standard weights and measures. The first serious attempt to make spelter in America was by Joseph Wharton, in Bethlehem, using oxidized ores from Friedensville. In 1856 or 1857 he employed Matthiessen and Hegeler to build a furnace. This was tried and abandoned. In 1859 Colonel Wetherill, of zinc oxide fame, built a spelter furnace that was not successful. Finally, in 1859, according to some reports, and in 1862, according to others, Wharton brought to this country Louis de Gée, an engineer from Liege, who built and operated a plant that, with some interruptions, continued to make spelter until 1911. In the meantime Matthiessen and Hegeler had built a works at La Salle, Ill., in 1858, and were operating successfully when the Civil War broke out. The plant was closed for a time, but opened again when the demand for spelter arose in 1862-3. The credit, therefore, for having first produced spelter on a commercial scale in this country belongs to Matthiessen and Hegeler.

The author traces the development of zinc smelting in different parts of the country, briefly describing the plants and their products. Matthiessen and Hegeler patented their spelter furnace in 1879, and it has been widely used since that time. In 1884 Hegeler patented his roasting furnace which is now used with modifications by every smelter in the country that makes acid. In addition to these important inventions, these metallurgists made many minor improvements in zinc smelting which have since been generally adopted.

The first zinc rolling mill was built by Matthiessen and Hegeler at La Salle in 1868, and has remained in operation ever since.

An entirely new process for making zinc oxide from ore was patented in the early '50s, and three patents were taken out in 1855 by Jones, Burrows and Wetherill, on almost identical lines. Burrows was employed at the Passaic Chemical Works. He states that "one night the flue from one of the furnaces that he was attending leaked, and he covered the hole with a piece of grate bar, throwing a shovelful of refuse on it. The refuse proved to be a mixture of coal and zinc ore, and the heat of the flue being sufficient to light it, Burrows soon noticed a cloud of zinc oxide coming off. He built a small furnace and repeated the experiment, and when he found that it worked again, showed it to the officers

of the New Jersey Zinc Company, among whom were Wetherill and Jones. The grate bars used were what are now usually called 'Wetherill grates,' but were in common use for boiler firing at that time in the vicinity of Newark, where they were made by Renton, who had a machine shop and foundry. Colonel Wetherill frequently stated that he had nothing to do with the invention of these grates, but his name has been persistently attached to them.

Colonel Wetherill proposed to Burrows that they work up an invention together, as Burrows had not the money to do so alone, but the proposition was declined, and each went ahead on his own account. The result was that three people applied for and obtained patents for substantially the same thing in the same year. Wetherill also took out patents for improvements in 1855-6-7-9 and two in 1868. The New Jersey Zinc Company acquired the patents of Jones and Burrows, but could not agree on terms with Wetherill. The latter shortly afterward sold a license to use his process to the Passaic Zinc Company. Both the New Jersey and the Passaic companies put the process in operation, as it proved to be a great improvement on those previously used. Everything went quietly until the Wetherill patent had nearly expired, when he brought suit against the New Jersey Zinc Company for infringement and accumulated profits. The suit that followed was long and hotly fought on both sides. The final decision of the court was that the furnace was Burrows' invention and the process Wetherill's and that half the profits were due to each. As the Zinc Company owned the Burrows' patent, it was obliged to pay half the increased profit due to the use of the invention, to Wetherill. The decision seems a very fair one, as while the original idea appears to have been Burrows', he had not sufficient knowledge or skill to develop it and make a working process of it."

The method of collecting oxide in bags was invented by S. T. Jones of New York in 1852 and is now universally used, not only for zinc oxide but other smelter products.

On the development of magnetic separation, the author says:

"About 1890, Messrs. J. P. Wetherill and G. G. Convers of the Lehigh Zinc & Iron Company, again attempted the separation, and this time with complete success. Their first method was to heat the ore to a very moderate temperature and separate on Wenstrom machines. This was patented by Mr. Convers, Dec. 20, 1892. They were not entirely satisfied with this method and continued their experiments, which resulted in the discovery, by Mr. Wetherill, of a new principle in magnetic separation—that of producing a highly concentrated field by using pointed pole pieces. Mr. Wetherill took out three patents on March 3, 1896, for the general principle, for the application of it to ores containing franklinite, and for the machine. A mill was built, and the willemite separated was used for the manufacture of spelter, and the franklinite for oxide, with a considerable increase in profits. Experiments were continued, and Sept. 28, 1897, Mr. L. G. Rowand patented an improvement in the machines, and March 7, 1905, another, which greatly increased the efficiency and has entirely displaced the earlier types in this country. In the earlier machines, both poles of the magnet were on the same side of the feed belt, with the result that less than half of the field was operative and the strongest part of it did no work. In Mr. Rowand's improvement, one pole is placed above the belt and one below; the former is pointed, the latter blunt. The entire field is thus available and the maximum possible lifting effect is utilized."

In 1901 the Blake-Morscher electrostatic process was patented. This and later patents were acquired by the American Zinc, Lead & Smelting Co., who also bought certain patents of P. H. Wynne and Millard Woodsome, both of which had been assigned to Charles H. Huff. These are the basis of the Huff process which is now used on suitable ores.

The successful application of flotation at Butte & Superior is the latest development in concentration of zinc ores.

Among new processes for treating zinc ores, the author notes hydrometallurgical methods using acids, chlorine and ammonia. None of these has come into commercial use, but a vast amount of experimenting has been done. Some work also has been done on electrolytic precipitation but without success, and the author is of the opinion that it is doubtful whether the method will ever be a commercial success. Electrothermic smelting also has received attention, notably by Woolsey McA. Johnson, who has made greater progress than any one else. The drawbacks to success are high power costs and difficulties in condensation. For ores containing metals other than zinc, the electric furnace may prove advantageous, but is not likely to become a competitor of coal or gas smelting purely for the production of spelter. The paper is concluded with tables and diagrams showing the production of spelter in the United States and the world.

In the discussion which followed, G. H. Clevenger thought that the author underestimated the importance of hydrometallurgy and electrolytic zinc refining. This is bound to become important at some places and interesting experiments are under way at Bully Hill, Palo Alto, Anaconda, Murray, Utah, and Trail, B. C. E. B. Braden said electrolytic zinc received at Selby was 99.7 per cent pure. L. H. Duschak emphasized that the power cost was not the controlling factor in electrolytic zinc production. S. E. Bretherton gave the cost as 1 cent per lb. with power at $36 per horsepower-year and as one-half cent at $17 per horsepower-year.

Lead

The Smelting and Refining of Lead.—A review of the present status of lead smelting in the United States, by Dr. H. O. HOFMAN of Massachusetts Institute of Technology, begins with the introduction of blast-roasting, which has revolutionized the details of practice. The use of this process has greatly increased blast-furnace capacity, and has modified the design of blast furnaces. Blast pressure has been reduced, and slags of higher silica content are produced. Coke consumption has been diminished. The following table gives a comparison of the work of the Huntington-Heberlein and the Dwight-Lloyd methods of blast-roasting at two different plants.

Item	At Murray	At East Helena
	Advantage Lies in Favor of	
Cost of installation	D. & L.	D. & L.
Cost of roasting	H. & H.	Even
Adaptability to charge	D. & L.	D. & L.
Metal loss	Even	Even
Physical condition of product	H. & H.	D. & L.

Lead bullion is desilverized by the Parkes process, excepting at Grasselli, Ind., and Trail, B. C., where the Betts electrolytic process is used.

"An important innovation with the Parkes process is supplementary treatment at Omaha, Neb., and East Chicago, Ind., of the refined lead by the Pattinson process in order to obtain from bismuth-bearing lead

bullion, as market product, corroding lead with less than 0.05 per cent bismuth. At Omaha metallic bismuth is produced; the bismuth content of lead bullion treated at East Chicago is not sufficiently high to warrant going so far.

"The treatment of blast-furnace matte has undergone some radical changes. Formerly this intermediary product was thoroughly roasted in different kinds of reverberatory furnaces, and added to the blast-furnace charges until its copper content had been enriched to about 14 per cent. The smelting of this pulverulent roasted product caused much trouble, as it separated from the siliceous part of the charge and disturbed the work of the furnace. All this has been obviated by rough-roasting the matte and then blast-roasting it either with siliceous ores or with the other ores that are to be used for making up the blast-furnace charge. The further treatment of 14 per cent copper matte is now carried on in basic converters. The older method, worked out at Maurer, N. J., is to treat lead-copper-iron matte in the same manner as copper-iron matte; i. e., with the additions of siliceous ores. A charge of matte and ore is blown until the ore has been scorified, the slag is poured off, and a second charge of matte followed by ore is given and blown; the operations are continued until the copper in the matte has been brought forward to furnish white metal, which is now blown to blister copper. A departure from the standard method of treatment has been made at the smeltery of the International Smelting Co., Tooele, Utah. Here the lead-copper-iron matte is blown without the addition of siliceous ore until practically all the lead and zinc have been volatilized to be collected in a baghouse. During the blow the iron is oxidized and a large part of the copper; the mixture is transferred to a basic copper-iron matte-converter working in the usual way with siliceous ore, the oxidized iron is scorified and the oxidized copper sulphurized. The result is that the lead blast-furnace has to treat only the lead fume of the baghouse instead of a large amount of lead-iron slag. The results of the modification have been most satisfactory.

"Very little speiss is produced in blast furnaces treating ores; some refineries, especially if they are unfortunate enough, at least from a metallurgical point of view, to have to treat arsenical silver ore from Cobalt, Ont., can not help but make speiss. There is no well established method of treating the unwelcome intermediary product. Blast-roasting has been successful in an experimental way; converting alone in a basic vessel has been a failure; converting with copper iron matte a success.

"The amount of flue dust formed in blast-furnace work has been greatly reduced. In spite of this, competition and the complaints of agricultural and other interests surrounding smelteries have forced these to make every endeavor to prevent fume and dust from passing off into the open. Thus most lead plants of any size are provided with baghouses, even when the pecuniary return they furnish is smaller than the outgo for cost, maintenance and operation. Much attention has been given to the filtration of fumes and dust. It has called attention to the important relation existing between the assay values of filtered fume and dust and the lead-silver content of matte and slag. In earlier times low values in matte and slag formed the criterion of good work; the baghouse has shown that very low assays of matte and slag are usually accompanied by high values of fume and dust; over-reduction caused volatilization. At present a balance is kept between the two.

"The Cottrell system of electric precipitation of fume has been installed at Garfield, Utah, for the collection of lead-bearing fume of copper-iron matte converters after it had been carefully tested on a working scale with a single unit. Experiments with blast roaster and blast-furnace gases have given results which show a satisfactory clearance of the gases from finely divided materials. At Trail, B. C., electric condensation is in operation."

In the discussion of this paper, E. B. Braden mentioned the tendency toward furnace shafts 19 ft. high and referred to a reduction by 50 per cent of the quantity of flue dust, due to sintering, at Selby.

Ore Dressing

Prof. ROBERT H. RICHARDS' paper on ore dressing was an interesting historical sketch of the advancement of the art from primitive methods to modern times, reviewing the development of tables and jigs, pneumatic, electromagnetic, and electrostatic separation, and finally flotation.

Fuels in Metallurgy

The symposium on the utilization of fuels in metallurgy had been arranged and edited by Prof. C. H. FULTON.

Burning pulverized coal in reverberatory furnaces was discussed in two papers. In the first, by D. H. BROWNE, the author gives certain data regarding the work at the Canadian Copper Co. The first furnace equipped for coal-dust firing was 112 ft. long by 19 ft. wide, with an extreme inside height of 6 ft. The bottom was an inverted arch of magnesite brick.

The coal was ground to 200-mesh and blown into the furnaces through five nozzles, into which it was conveyed by screws. Early operations showed that furnaces designed along the lines of grate-fired reverberatories were not adapted to the new practice. The roof required frequent repairs on account of the excessive heat. The magnesite bottom was replaced with silica, and the roof was raised to give a combustion space 6 ft. 3 in. high above the skimming line. The manner of charging was changed, the ore being introduced along the sides of the furnace. These changes resulted in increased ratio of charge to fuel. Thus during the first three months of 1914 the monthly average of tons of charge smelted per ton of fuel was 5.0, 5.65 and 6.77.

In the paper by E. P. MATHEWSON, Anaconda practice is briefly described. Two points are essential for the success of coal-dust firing: the coal must be dry, containing less than 1 per cent moisture before pulverization, and the grinding must be carried to a very fine point. Preferably, 95 per cent should pass a 100-mesh screen, and 75 per cent through 200-mesh. The flame is as easy to handle as gas. About 50 per cent of the ash is absorbed by the charge and the balance caught in the flue connection to the waste-heat boiler. With the use of coal-dust firing and side-wall charging, it is no longer necessary to stop the furnace for fettling, and in the larger furnaces the flow of slag can be continuous as in copper blast furnaces.

Gas producer development is discussed in a paper by Z. C. KLINE. The author finds the gas producer growing in popularity as natural gas becomes scarcer and oil more expensive. Development has been toward mechanically operated producers and toward designs for gasifying bituminous coal and fixing the tarry constituents. Mechanically operated producers are more expensive to install, but labor cost is reduced, capacity increased and more uniform gas produced. The gas-producer industry suffered somewhat from installa-

tions that did not come up to expectations, but the earlier difficulties have been simplified, and many plants are now working satisfactorily.

The trend of gas producer operation will probably be toward the perfection of mechanical types and more experiments toward simplifying and cheapening the methods of obtaining clean producer gas, and, no doubt, a great deal more attention will be paid to the operation of the producers already installed, especially along lines of labor and technical efficiencies. A great many firms now have appliances for checking up quality of gas, amount of coal used, and temperature control. At last, manufacturers are realizing that a gas producer cannot be run efficiently without competent men.

Surface combustion is reviewed in a paper by Prof. C. E. LUCKE, the inventor and original patentee of the process. When air is perfectly mixed with gaseous fuel, in chemically combining proportions, the products of combustion are free from both fuel and oxygen. The mixture burns at the maximum possible rate because of the absence of flame volume and regardless of the nature of the surrounding atmosphere. For the commercial applicability of the combustion of such explosive mixtures, a definite localization of combustion zones is necessary, and means must be provided to prevent "back flash" and "blow off" due, respectively, to inferior and excessive flow velocity as compared with that of flame propagation. Back heating from the combustion zone along the walls of the feed passages to the mixture supply point, must also be prevented, either through thermal resistance or cooling by circulation of air around the passages. Perfect cooling prevents "back flash" regardless of flow velocity; with imperfect cooling it is prevented by a drop in pressure through supply exits varying from 0.1 in. water column to larger values, according to the size of the passages and burning rates of the mixtures.

"Excess exit velocity from the passages, which is normally necessary to prevent back flash, must be promptly reduced to prevent blow off, by spreading the mixture stream just beyond exit from the passages by baffles of solid refractory surfaces or by porous beds such as layers of granular refractory material, loose or bonded. These refractory spreaders become incandescent, permanent fire beds, converting a maximum of the heat generated into the radiant form, and they incidentally act also as accelerators of the combustion reaction.

"Accordingly the combustion zone may, it has been found, be definitely and permanently localized by utilizing the properties of the explosive mixtures themselves, and as a result there is now available for commercial application a new method or system of gas combustion, characterized by maximum possible rate of combustion, by maximum possible temperature of gases, because of minimum weight of products per pound of fuel, and by products containing normally no free oxygen and no unburned fuel, though by adjustment of proportions the products may be made either oxidizing or reducing."

Experiments on Sewer Pipe and Drain is the subject of Bulletin No. 7 of the Utah Engineering Experiment Station, Salt Lake City. The author is Prof. E. H. Beckstrand. Pipes were tested under all sorts of stresses, internal and external, and very complete information is given.

The **Brown Instrument Company,** Philadelphia, Pa., has just let a contract for an addition which will furnish nearly 50 per cent additional floor space. The factory, which a year ago seemed sufficiently large, has been outgrown, due to the large demand for Brown pyrometers for high-temperature control.

Opportunities for the American Chemical Industry*

BY EDWARD EWING PRATT

Chief Bureau of Foreign and Domestic Commerce, Department of Commerce, Washington, D. C.

The Department of Commerce is deeply interested in the chemical industry and aims to facilitate its development in every way. The department realizes that no other branch of American industrial activity has been forced to deal so swiftly and effectively with a great variety of extremely difficult problems. The chemical industry of the United States along with other industries found a very serious situation at the outbreak of the European war, and the last year has been a period of readjustment and reorganization.

The National Exposition of American Chemical Industries is significant because it illustrates the fact that American chemists and American chemical manufacturers have, through their own inventive skill, their own talent for organization, and their own thorough knowledge, been able to accomplish a great deal during the last twelve months. It can be fairly said that at the present time the American chemical industry is well established and that American firms need no longer be dependent for chemicals upon any foreign country. This is a tremendous accomplishment and it is extremely significant in the development of American industries.

The effects of the great European war have been noteworthy in our American industrial life. On the whole, they have been of a twofold nature; there are direct, visible results, essentially of a transitory nature and destined to disappear with the approach of peace. There are other results less evident to the eye but increasing with every added day of the conflict and bound to be of far-reaching import in the development of our industries.

Among the more important temporary effects of the war are those which have to do with the furnishing of supplies for the various belligerent activities in Europe. We are furnishing not only large quantities of foodstuffs and live stock, but considerable quantities of shoes, wearing apparel, saddlery, motor trucks, railway supplies, iron and steel in all kinds of shapes and forms; lead, zinc and copper; fire-arms and ammunition. For the time being these specialties are stimulating considerable activity in our industrial plants. Whether it is an altogether healthy activity, and whether it will not lead to serious economic consequences is a question. In so far as our manufacturers count on this activity as definite increases in their business and as a permanent increase in production, so far will they be unprepared for the cutting off of this activity at the end of the period of hostilities.

A review of the chief industries ministering particularly to the temporary needs of the belligerents across the Atlantic shows clearly the final outcome will be a very material addition. Part of this plant will be simply anticipatory of the normal growth of the company's mechanical equipment. Part must lie idle in time of peace, but is a distinct asset in the national preparedness for an adequate defense against attack. The remainder furnishes at once products needed in the healthful expansion of our industries, and particularly of the chemical industry.

Less conspicuous and spectacular, but of far greater permanent value, is the impulse given to the manufacture on American soil with American raw materials of a variety of articles for which we have heretofore been dependent upon foreign skill and enterprise. In a more

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* An address made before the First National Exposition of Chemical Industries at New York City on Sept. 25, 1915, slightly abstracted.

or less uncomfortable way we have suddenly been brought to recognize the folly of shipping vast amounts of crude material of our farms, forests and mines 3000 miles across the ocean and buying it back in a manufactured form at a vastly enhanced price. We have likewise come to recognize the absurdity of allowing many natural products of the tropics, of South America, of the Far East, to find their way to Europe and of paying foreign intelligence and skill to transform them into articles of daily need in our lives.

The complete cessation of imports from Germany and Austria and the serious restriction in our purchases from many other countries have taught us these two lessons. It is in the practical application of these lessons that the American people will derive their fullest benefit from this otherwise so deplorable world conflict. American skill, ingenuity, adaptability, inventive talent, scientific attainment and general enterprise have promptly rallied to meet widespread demands to establish on our own soil the permanent manufacture of a number of wares, some of minor, others of major importance. The return of peace will see them well rooted and able to withstand foreign competition.

There are a number of industries which might be cited where we have heretofore been dependent upon Europe and have since the outbreak of the war begun to manufacture for ourselves—the curved faces of our clocks and watches, fine brushes for water-color use, chloride and carbonate from domestic barium minerals, chemical porcelain and optical glass are cases in point.

Prior to the war we imported from Europe, chiefly from Germany, coal-tar dyes valued annually at nearly $10,000,000. Our vast textile interests, the great industries producing paper, ink, varnish, pigments, etc., were dependent upon these importations for the element of color in their wares. To every tailor, to every milliner, in fact, to every consumer of colored articles, it has been a matter of vital necessity that there should be no interruption of the regular arrival of the hundreds of varying hues produced upon the banks of the Rhine from prosaic coal tar.

There was a limited production of these artificial dyestuffs in the United States. Unfortunately the domestic production has been dependent hitherto upon Europe, and again chiefly Germany, for its raw materials, the semi-manufactured so-called intermediates, such as aniline, salicylic acid, etc.

The supplies of intermediates ceased with the outbreak of the war. The importations of finished dyes from Germany were intermittent and finally stopped altogether in March of the present year. Conditions threatened to paralyze the activities of our textile interests and of allied industries. There has been a certain amount of displacement in the mechanism of production, unavoidable under the circumstances, as the available stores of artificial dyes steadily disappeared from the storerooms of textile and other mills.

Thus far the disaster has been less serious than we feared it might be four months ago. Forced to make material changes in designs and in processes with more or less incidental losses, there is little doubt but that the sum total of the losses borne by American industries during the year 1915 in consequence of the cessation of the importations of foreign coal-tar dyes will far exceed the amount of capital needed to establish upon our own soil a complete self-contained American coal-tar dyestuff industry, using exclusively American crude materials and meeting adequately all the nation's needs for artificial colors.

In this connection the users of dyestuffs in this country should have the co-operation of every consumer. Up to the present time manufacturers have been using the stores of dyes which were left on hand or which have been meagerly supplied since the opening of the great war in Europe. Before our own industry can produce the necessary amount of dyestuffs there will be a certain hiatus during which it will be impossible to get the same kind of colors and the same qualities and shades of colors as has been possible heretofore. Garment wearers—men. women and children—will have to be content with plainer and more prosaic standard colors. Consumers will have to forego the use of the more intense and delicate colors which were obtainable from the various coal-tar products. This applies not only to outer garments, but to shirts, women's waists, neckties, hosiery and underwear. In fact, to everything in which dyes are used for the production of fine colors in the daily wear of people.

It therefore behooves the people of this country to be considerate, and if only plain colors are obtainable, or if colors are used which do not stand the test of exposure to weather and climate, not to blame the manufacturer of the garment or the manufacturer of the colors.

American industry, however, has taken hold of this problem in a particularly rapid and satisfactory manner. Each week witnesses the addition of new firms engaged in solving the problem of a domestic supply of coal-tar colors either by furnishing crudes or intermediates for finished dyes. Increasingly large amounts of capital are being devoted to this new industry, and there is an intelligent awakening of both capital and enterprise to the opportunity offered for establishing a fairly complete coal-tar chemical industry on American soil.

One of the especially interesting features of this exposition is that of a pioneer company in Buffalo, which has been able to prove that the United States can create a complete comprehensive and self-contained coal-tar chemical industry, fully capable of meeting the demands of the great textile industry and the scores of allied interests in which these colors are of vital importance. In fact, American chemists have concentrated their efforts upon the solution of the dyestuff problem, and, noting the creative ability which is being applied to these problems, I am sure that a solution will be reached.

The United States has also been dependent upon Europe for its supplies of potash. These supplies have been used exclusively for fertilizers which are especially needed in the cotton plantations of the South and are indispensable to the crystal products of our glass works. The United States has been content to receive its supplies from Europe. These supplies were suddenly cut off. Under these conditions the American manufacturer has turned to the resources of his own country and has been able to arrive at a practical solution of this very difficult question, for a method has been discovered by which the tons of kelp on our Pacific coast can be utilized as a means for securing potash supplies. It is therefore with peculiar satisfaction that I have learned from the official of the Bureau of Foreign and Domestic Commerce who has been in charge of the investigation in this field that several processes of real economic promise have been discovered, and there is no doubt that the securing of potash from the kelp fields of the Pacific will soon be established upon a broad industrial basis.

It would be scarcely in accord with the usual development of industry to recommend that we should slavishly imitate the example of any foreign country. It is worth while, however, to consider the methods and success of Germany in developing her chemical industry. In 1860 the chemical industry of the world was developed to its highest extent in England, with France a close second.

It was not until about 1875 that Germany began to show great activity in this industry. Her development, however, was as rapid as it was unforeseen, and in the face of serious obstacles. Even for many years after this date Germany had to rely upon imports for many of the principal staple materials required by the chemical industry, such as soda ash, bleach, coal tar, ammonia compounds, etc., from other countries, especially England. Even as late as 1879 Germany's imports of soda amounted to 24,000 tons, which constituted the entire consumption for that year. In 1910 the imports of soda had fallen to 154 tons, while the exports had amounted from zero to 62,500 tons, representing the excess of production over consumption.

Similar instances illustrating the growth of the German chemical industry can be quoted in any number. Not only did England and France have the start of Germany in the matter of raw materials, but those countries also to a considerable extent had a corner on the market for technical skill which was required in the development of the chemical industry. In spite of these handicaps, Germany went forward to such a point that before the opening of the European war she controlled many branches of the chemical industry and other countries of the world went to her for their supplies. This is particularly true of the coal-tar industry and the manufacture of synthetic dyes.

Chemistry has truly been called "The Intelligence Department of Industry," and it is therefore peculiarly important that we should develop a chemical industry in the United States. It is not merely a matter of a single industry or the matter of attaining increased efficiency or a wider variety of products in one industry, but applied chemistry is largely the successful utilization of by-products and, therefore, the development of a chemical industry in the United States means increased efficiency and increased economy in every industry in this country.

It is also pertinent to point out that perhaps the fundamental reason for the peculiar success of the German chemical industry has been the willingness to devote years and years of effort, of careful scientific experimentation to the development of a process or a new product. It is this long-time investment for the future, the idea of unceasing experimentation, that American industry must learn.

The progressive development of industry—this is particularly true of the chemical industry—parallels the development of science and knowledge. The nations whose natural products are the most intense and the best utilized are also those which attain industrial supremacy.

The United States should be independent of all foreign sources for all its chemicals, for the United States has within its own boundaries the raw materials for the production of such chemicals. This exposition tonight illustrates the fact that chemical manufacturers are alive to the possibilities of the present situation. It shows, too, that the national government is earnestly seeking to encourage and facilitate the growth of the nation's chemical industry. The Bureau of Foreign and Domestic Commerce, which has had such an active share in this exposition and through the work of its own commercial agent is attempting to solve some of the difficulties which have confronted some of our chemical industries, feels that the chemical manufacturers of the United States are opening up a new epoch in American industry, and that as a result of the transformation which is taking place the United States will not only be a producer of its own chemical needs, but that the United States will undoubtedly secure a large share in the chemical markets abroad.

Accident Prevention in the Chemical Industries*

BY FREDERIC W. KEOUGH
National Association of Manufacturers

A recent bulletin of the Bureau of Labor Statistics of the U. S. Department of Labor, presents an estimate that 25,000 fatal industrial accidents occur annually among American wage earners and approximately 700,000 accidents occur which involve a disability of more than four weeks' duration. The industries which contribute to the greatest number of fatal accidents are railroad and agricultural work, each causing about 4200 fatalities per year. Coal mining causes more than 2600; building and construction work only 1900, and general manufacturing about 1800.

In an effort to get some statistics on accidents and accident prevention in the chemical industries, I wrote to some sixty concerns and to my first letter received only three acknowledgements of any sort. A second letter to the same parties brought little more in the way of results. From this one might assume that chemical establishments are not interested in accident prevention. There is, however, excellent testimony from a few sources to the contrary. It may be concluded, nevertheless, that there are no particular hazards in the chemical industries, other than those of running machinery. Pains should therefore be taken to educate workmen when engaged on special jobs and proper remedies should be near at hand in case an accident should occur. For instance, as a special aid soda ash should be stored in convenient places in case of breakage of acid carboys or similar injuries to the men. A first-aid department should be installed to treat minor injuries, and if the size of the plant justifies, a physician should be on the house staff. For emergency use there is nothing better than the N. A. S. O. jar—N. A. S. O. meaning National Affiliated Safety Organizations, namely the National Founders Association, National Association of Manufacturers, National Metal Trades Association, and National Electric Light Association.

This jar was developed to meet all requirements of a compact, convenient, sanitary-first-aid outfit. It is structurally strong and its arrangement allows quick removal of any article without disturbing the rest. It includes every material which a large conference of physicians with an extensive experience in the treatment of injuries, agreed upon as necessary for effective first-aid treatment by laymen. The jar is especially useful as it can be transported readily from place to place. Some employers, in fact, place a jar on every truck or wagon used in connection with outside work. The jar, like the standardized safety goggles, foundry leggings and shoes, is sold at cost price as there is no intention to make a profit on the devices.

First aid, in order to result in the decrease of accidents and in the prevention of serious consequences following slight injuries, is dependent upon three factors, namely:

(1) Properly equipped and properly managed emergency rooms with competent first-aid man in charge in the smaller works; in the larger works, attendant physician and nurses are requisite.

(2) The intelligent and willing co-operation of every workman in the prevention of accidents. All workmen should familiarize themselves with, and put into practice, the company's rules requiring the immediate reporting to the emergency room of all injuries for treatment.

*An address delivered at the National Exposition of Chemical Industries at the Grand Central Palace, New York City, Sept. 22, 1915.

(3) The instructions of every man at the works to see that proper attention is given to his injuries in order to prevent their becoming serious. This may be accomplished by the organization of first-aid squads which, of course, should be properly instructed by the physician in charge in all the elements of emergency practice. One of these squads should be organized in each department, and it will be of decided advantage to arrange for a similar rotation of service as is operative in the work committees.

The timely treatment of injuries will always result in a rapid cure and consequently in a reduction of expenses.

Chemical companies, let us believe, are interested in accident prevention in a general way even though they have few recommendations of ways and means especially adaptable to their industry. It is a source of great satisfaction to learn that the safety department of *American Industries*, the magazine of the National Association of Manufacturers, has enjoyed the appreciation of the chemical industry. In the promotion of safety work we have issued a four-page supplement for the last three years, devoting each issue to some particular topic and showing in colored illustrations, innumerable devices that may be made in any shop.

As to causes of accidents in the group comprising manufacture of paints, oils, etc., an indication as to the principal sources is found in a bulletin of the New York State Department of Labor for 1912 and 1913, which shows in 2642 cases, 575 accidents caused by fall or weight of objects; 508 by miscellaneous accidents; 449 through heat or electricity; 341 by falls; 292 by working machinery; 168 by hand tools; 136 by conveying and hoisting machinery and 86 by power transmission.

The accidents directly related to the manufacture of chemicals are largely occupational diseases or burns from acids or poison by some mineral. Especially dangerous minerals are lead, arsenic, mercury and phosphorus. In addition we have the danger of acids which corrode the skin and act as caustic and in vaporous state attack teeth. Wood alcohol produces blindness if taken internally or even if breathed in large quantities; and gases such as carbon monoxide, methane or marsh gas are deadly. In fact, all of the hydrocarbons are more or less poisonous. One of the ever-present dangers is that if there is any corrosion of the skin or any skin disease which may arise from certain products, such as varnish, other diseases are engrafted on it. The principal thing is cleanliness of the hands, so wash basins are necessary and many times gloves. Some of the anilines are also poisonous. Dust is also a factor in the manufacture of some chemicals. There is danger in many lines of explosion, particularly now in the rapid manufacture of so much powder and high explosives. The principal lines of prevention are dust hoods, washing, etc.

The list of industrial poisons is a long one and since they attack from so many points, they must be studied closely. Here is the list that is entitled to special attention: Acetaldehyde ethylaldehyde, acridine, acrolein, ammonia, amylacetate, amylalcohol, aniline, aniline dyestuffs, antimony compounds, arsenic compounds, arseniureted hydrogen, benzine, benzol, carbon dioxide, carbon disulphide, carbon monoxide, chloride or lime, chlorine, chlorodinitro-benzol, chloronitrobenzol, chromium compounds, cyanogen compounds, diazomethane, dimethyl sulphate, dinitrobenzol or binitrobenzol, formaldehyde, hydrochloric acid, hydrofluoric acid, lead, manganese dioxide, mercury, methyl alcohol, methyl bromide nitraniline, nitrobenzol, nitroglycerin, nitronaphthalene, nitrous gases, oxalic acid, petroleum, phenol, phenylhydrazine, phosgene, phosphorus, phosphorus sesquisulphide, phosphureted hydrogen, picric acid, pyridine, sulphur chloride, sulphur dioxide, sulphureted hydrogen, sulphuric acid, tar, turpentine oil.

Since these attack through the respiratory organs, by absorption through the uninjured skin, through the digestive organs, specific measures for the protection of workers must be devised. The suggestions laid down by Dr. R. Fischer of Berlin, are comprehensive enough to repay study and application. These are:

1. Properly adapted buildings, thick walls of separation for dangerous rooms, good lighting, facilities for keeping the workshop clean and for effective ventilation.
2. Apparatus adapted to its special purpose, whenever possible, closing tight in every part.
3. Appliances for accomplishing the arrest of gases and dust at their place of origin, their removal (by exhaust fans) and in a suitable manner rendering them innocuous or collecting them, thus preventing them from entering the nose and mouth.
4. So far as possible, avoidance of direct contact with poisonous materials or substances injurious to health in working with, transporting, or packing them.
5. The displacement of particularly dangerous labor methods and materials by the introduction of less dangerous labor processes and materials, as well as by the employment of materials satisfactorily pure chemically.
6. Instruction of workmen just entering upon an occupation concerning the properties of the poisonous substances extracted, manufactured, used, or otherwise evolved, and, whenever possible, caution leaflets should be put into the hands of the workers.
7. The repetition of this instruction at frequent intervals.
8. Posting of precautionary regulations and warning placards containing admonitions for the exercise of special caution and enjoining the observance of measures for insuring safety. Constant supervision of all dangerous employments by expert and responsible persons.
9. Employment by appropriate means for personal protection as work clothes, caps, gloves, goggles, and, as necessary adjuncts, mouth and nose shields, respiratory masks and the like, in case the appliances named in rule 3 are inapplicable.
10. Practice of bodily cleanliness by the use of wash, bath and dressing rooms, the use of special rooms for eating, separate wardrobes for street and work clothes, and frequent, nonhazardous cleansing of the clothing.
11. Immediate report of symptoms of indisposition, attention to wounds of the skin caused by the handling of corrosive materials, the speediest employment of an unexceptionable antidote giving promise of success at the very first symptoms of poisoning, with the simultaneous summoning of a physician.
12. The installation of a healthy working force capable of withstanding exposure to the poison. Temporary or permanent exclusion of sick workmen from the dangerous departments of the industry. Medical examination of the workers in dangerous employments at suitable intervals. Under certain circumstances there should be a change of work in occupations giving rise to chronic poisoning.
13. The utmost possible reduction of the hours of labor in dangerous employments.

Satisfactory statistics are not available, showing the number of cases of poisoning resulting from the inhalation of poisonous fumes and vapors in the various industries of the United States. Physicians in this country have reported many cases that have come under their observation, insurance companies have had considerable similar experience, and other cases are brought to light through the reports on occupational diseases that are required by law in some of our States. These returns are incomplete, however, and they utterly fail to reveal the seriousness of the situation.

It is of the utmost importance that the men who are to work at dangerous occupations be carefully selected, because some persons, by reason of physical infirmities or deficiencies, are totally unable to withstand the unhealthful conditions that are sometimes associated, more or less unavoidably, with our manufacturing plants. Before engaging in hazardous work of this nature, each man should be carefully examined by a

competent physician, and similar examinations should be made thereafter, periodically and regularly. In plants making use of hazardous processes, there is no doubt that both the efficiency and the health of workmen are better when reasonably short hours are the rule, and when stated rest periods are allowed.

Heads of departments should co-operate with their men in having all thoroughly aware of the hazards of any special operations. They must impress on their workers that among them should be foremost the accident prevention spirit. They should realize as vividly as do the managers of the plant that accidents are bad business, aside from humanitarian and sentimental considerations. Accidents increase insurance premiums and it is only a common business principle that it is necessary to reduce expenses as far as possible in this and every other direction.

The accident insurance companies and the State factory inspectors are entitled to much credit for the reduction of accidents through their insistence that the requirements made by the inspector are complied with. Factory inspection and inspectors have grown into something like a burden in all lines of industry; in the direction of safety inspection can scarcely be too frequent or too searching.

In a chemical works there are machine shops in the buildings, woodworking and similar mechanical risks, that can be solved according to the best modern practice in safeguarding and safety appliances. All necessary precautions should be taken in chemical plants to install proper safeguards around machinery, elevators, boilers, railway tracks, etc.

Beyond these risks are those inherent in the processes of manufacture of the so-called heavy chemicals, sulphuric, nitric, muriatic, hydrofluoric acids and their by-products, sulphate of alumina and other alkaline products. There is a certain negligible risk from fumes in the operation in the manufacture of acids, but this is very remote, the most dangerous fumes being those produced in the manufacture of nitric acid, which are released only through the breaking down of some portion of the apparatus. The most dangerous of the acid burns are hydrofluoric, nitric and sulphuric. The burns caused by these acids getting on the skin are very severe and painful.

To protect the eyes of men working with these acids in any situation in which there is danger of splash should be obliged to wear rubber-lined goggles, fitting close to the face. All bad results from getting the acid on the person can be avoided entirely by thorough washing with plain water which dilutes and removes the chemical from the skin.

The General Chemical Company, which has an admirable safety organization, furnishes men working on acid pipe lines with a rubberized cloth hood with mica covered eye openings to be worn whenever they are loosening or tightening valves or separating flanges, to guard against a sudden squirt of acid which might strike them in the face and eyes. In working in the alkaline processes, the men wear rubber gloves furnished them.

Cooling pans containing hot liquids are railed off to a height of 3 ft. to prevent men from stumbling and falling into them. In dusty processes, as in other industries, men are obliged to wear respirators of some approved type.

In the heavy chemical industry the matter of ventilation of process buildings is simple, since in general they are large and high with ample openings near the roof for the escape of any gases or fumes. The chief means adopted by the General Chemical Company to prevent the industrial accidents inherent in the manufacture of chemicals is the careful education and supervision of the men.

An effective device for use in filling laboratory stock bottles for strong acids from carboys is forcing the acid, or the ammonia, from the carboy through a glass tube by means of compressed air. The air is freed from impurities by passing it down through a 5-ft. iron pipe filled with fairly fine coke. An attendant must always be present with the regular operator during the filling of these bottles.

Systematic schemes for preventing accidents are not new in the United States. Some large employers have had efficient systems for a number of years, but efforts were not sufficiently widespread and, as a national movement, accident prevention was in the United States up to a few years ago far behind other industrial nations. American statesmen, employers, economists, insurance experts and humanitarians of all classes have called attention to the need of greater and more concerted action and much has been done in the last three years.

The present time finds the people of our country far more active in accident prevention than any past period. This activity will continue and increase for years to come and those who have had the opportunity to investigate this subject here and in European countries believe that we are gaining headway and that within a few years will overtake some of the nations who have preceded us in the movement from fifteen to twenty-five years.

In the face of all the safety work that is being done by societies, by associations, by manufacturing plants, by individuals and the press, it is strange that one finds Secretary Frank Morrison of the American Federation of Labor, in a speech last Labor Day, uttering for obvious effect this grave misrepresentation: "Let us not forget that 30,000 of our fellow-countrymen engaged in gainful occupations are killed every year. Men talk about preparedness, but never a word of protest at the annual loss of these thirty regiments that are silently swept into unknown graves *that dividends may continue.*"

An investigation made of a large number of concerns that have reduced their accident records an appreciable per cent, proves conclusively that mechanical safeguards only prevent from 25 to 40 per cent, while the remaining 75 per cent can be prevented only by education, inspection and co-operation of the workmen. Even in the smallest plants, it is necessary to have some form of a safety organization in order to keep employees interested and on the look-out not only to safeguard themselves from injury, but their fellow workmen as well. One of the greatest means of getting the desired co-operation is that of allowing men to serve on committees and give them some responsibility in the work. Where this plan has been followed, 95 per cent of the suggestions for safeguarding submitted, have been found practical and were adopted.

The central committee should have as a member at least one of the executive heads of the concern, not only to give it prestige but authority as well. It should serve as a general clearing house for all safety matters and devise ways and means for keeping safety interest aroused and obtaining the co-operation of employees. Regular meetings should be held, preferably monthly, at which time all serious accidents should be discussed and measures taken to prevent their future occurrence. Proceedings of the shop committee should be considered and action taken on recommendations offered, and guards ordered installed that are deemed necessary. The report of periodical inspection made by the safety man should be considered and investigations made of dangerous conditions reported.

The shop committee should meet at least monthly and all dangerous conditions discussed and suggestions made to remedy them. The personnel of the committee should be changed at least every three months so that as many as possible can be drawn into intimate touch with the work and the interest aroused. Since workmen make the best inspectors, they should be encouraged to report conditions in their departments that they usually see in the course of their regular duties, as with plants of the size here discussed, it is hardly necessary to devote a definite period of time to inspection work.

Even in plants of the smallest size, some one person should be detailed to see that safeguards are constructed in accordance with various standards adopted and report to the central committee, when the work has been completed on the progress that is being made. Such a man can usually be found in the drafting or mechanical departments and should be required to make periodical inspections of the entire plant and report on conditions found.

One of the greatest factors is keeping employees interested in a regular "booster" or get-together meeting. A "smoker" often serves the purpose, at which time stereopticon or motion pictures relating to safety can be shown and by the aid of talks by various members of the firm or an authority on accident prevention, the subject can be impressed on their minds and their co-operation obtained. At these meetings the cause and prevention of accidents should be freely and frankly discussed which will tend to bring a closer relationship between employer and employee, which will not only aid in accident prevention, but will aid in disseminating any industrial discord that may have a tendency to arise. The solution of the whole accident problem is to get the men with you, then do your part, and accidents will take care of themselves.

It is conceded generally, says a well-known safety engineer, that the older employees resent the safety idea more than the younger men, and it is only natural that this be true. After a man has operated a machine for a number of years without sustaining an injury, he naturally would feel as though it was a reflection on his ability to have safeguards applied. This condition is particularly found in small shops, and it requires some tact in approaching the employees and gaining the desired confidence. After such an employee is once won over to the side of safety, he will usually prove a very ardent "booster" not only in preventing accidents, but in pointing out dangerous conditions.

First National Exposition of Chemical Industries

To supplement our report of the exhibits given in our issue of Oct. 1, we herewith give an account of a few exhibits which were omitted through error of the printer in our last issue.

Condensite Company, Bloomfield, N. J.—Exhibit of the various products made from "condensite," among which were the Edison records, switch board meters, the Remy ignition generator, golf clubs, automobile steering wheels and numerous other articles of all kinds. Their exhibit also included Hallowax, which is made from chlorine and napthalene and used for fire extinguishers and in places where a high specific inductive capacity is required. Mr. Sanford Brown was in charge.

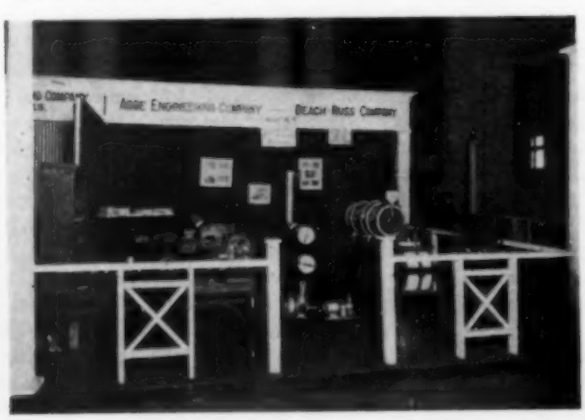
L. O. Koven & Brother, Jersey City, N. J.—Showed small models of water still and benzol still, and also a large size Kelly filter press manufactured by them. Dr. Emil E. Lungwitz was in charge.

Standard Aniline Products, Inc., New York City.—Showed samples of nitraniline, beta naphtol, permanent red, sulphur black and para-nitraniline.

Werner & Pfleiderer Company, Saginaw, Mich.—Exhibited four small models of their kneading and mixing machines and one large "Universal" mixing machine was shown with the top removed so that inside mechanism could be seen. Mr. F. H. Banbury was in charge.

The following list comprises the names of those who registered either at the booth of the American Electrochemical Society or at the booth of METALLURGICAL AND CHEMICAL ENGINEERING. Where no address is given New York City is understood:

Paul O. Abbé; Wm. H. Abeling; Aberman & Son; Jerome Alexander; B. Alperowitz; M. E. Alpers, Dover, N. J.; L. T. Alton; H. S. Amer, Bloomfield, N. J.; American Alkali & Acid Company, Bradford, Pa.; Wm. C. Andrews, Orange, N. J.; D. W. Armstrong; Louis V. Aronson, Newark, N. J.; D. Irving Ashworth, Wappinger Falls, N. Y.; L. H. Baekeland, Yonkers, N. Y.; Robt. J. Ball, Newark, N. J.; Will H. Baltzell, Pittsburgh, Pa.; John H. Banks; E. J. Bartlett, Hanover, N. H.; Chas. Baskerville; J. W. Beck, Rosiclare, Ill.; A. E. Bellis, Chicopee Falls, Mass.; R. C. Bergen; H. S. Blackmore, Washington, D. C.; D. M. Bliss, Kingsland, N. J.; J. E. Bloom, Brooklyn, N. Y.; E. Blough, Pittsburgh, Pa.; P. L. Blumenthal, Lexington, Ky.; Walker Bowman; W. H. Baynton, Grasseli, N. J.; Chas. S. Bradley, Linn Bradley; Walter M. Bradley, New Haven, Conn.; William Brady, Chicago, Ill.; H. B. Branerr, Seattle, Wash.; E. J. Bremnesen, Elmhurst, L. I.; T. Lynton Briggs, Flushing, N. Y.; W. H. Broadhurst, Brooklyn, N. Y.; H. E. Brown, Kingston, N. Y.; C. L. Bryden, Scranton, Pa.; Lucien Buck, Rochester, N. Y.; Robt. H. Buckle, Mechanicville, N. Y.; R. Buisemeister; W. G. Bullard, Dover, N. H.; D. G. Bunicke, Philadelphia, Pa.; C. F. Burgess, Madison, Wis.; J. W. A. Butler, Brooklyn, N. Y.; Alison Butts, Chrome, N. J.; J. R. Cain, Washington, D. C.; Harry S. Calvert, Pittsburgh, Pa.; R. P. Calvert, Henry Clay, Del.; Arthur J. Campbell, Bridgeton, N. J.; Frank W. Cann, Newark, N. J.; Jessie Y. Cann, Urbana, Ill.; H. Carmichael, Boston, Mass.; H. M. Carter, Norwood, Mass.; George S. Cary; C. F. Chandler; P. L. Charter, Bridgeport, Conn.; J. B. Churchill, State College, Pa.; G. W. Clarke, Cleveland, Ohio; E. A. Colby, Newark, N. J.; Albert A. Cory; Alfred H. Cowles, Sewaren, N. J.; J. R. Crocker; W. L. Cummings, Philadelphia, Pa.; F. W. Cunningham, Orange, N. J.; Thos. Darlington; Ralph W. Deacon, Chrome, N. J.; C. F. De Ganoke; J. R. de la Torre Bueno, White Plains, N. Y.; Demaras Bros., Athens, Greece; C. H. Demproolf, York, Pa.; H. C. Diercks, Ithaca, N. Y.; Carl Dittmar; Wm. Donald, Ridgefield Park, N. J.; Chas. A. Doremus; L. B. Drekerson; Gustav Drobegg, Brooklyn, N. Y.; J. W. Drummond; Wm. R. Duggan; E. N. Dukern, Monte Carlo; Arthur J. Dwight; Thos. A. Edison, Orange, N. J.; L. A. Ehnhardt; August Eimer; Carleton Ellis, Montclair, N. J.; N. H. Emmons, 2d, Englewood, N. J.; Henry C. Enders; H. W. Engle, Marietta, Pa.; H. W. Faint, New Brunswick N. J.; E. W. T. Faint, Roselle Park, N. J.; J. Wm. Fehnel, Bethlehem, Pa.; P. B. Fehl, Reading, Pa.; Colin G. Fink, East Orange, N. J.; Staats L. Fink, Newark, N. J.; Chas. B. Foley, Ann Arbor, Mich.; W. A. Forbes; Albert Ford, Bridgeport, Conn.; Chauncey E. Foster; C. Fuld Frank; M. M. Franklin, East Orange, N. J.; H. A. Frasch; F. W. Frerichs, Jr., St. Louis, Mo.; R. C. Gardner, York, Pa.; David S. Giles, McKeesport, Pa.; J. S. Goldbaum, Philadelphia, Pa.; H. A. Goldman; S. M. Goldsmith; W. E. Gray, Elyria, Ohio;



TWO MORE EXHIBITS FROM FIRST NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES

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Graphite.—The two uses of graphite that seem to have shown the greatest gains in 1914 are its application to lubrication and as a preparation to lessen boiler scale.

Monazite, Thorium and Mesothorium is the title of Technical Paper 110 of the Bureau of Mines. The author is Mr. Karl L. Kithil. This paper describes the properties, occurrence and methods of mining and milling monazite, and methods of preparation of thorium and mesothorium.

A New Electrolytic Method of Sewage Disposal*

BY J. C. OLSEN

The process of sewage disposal described in this paper has been in operation at Elmhurst in New York City for more than a year.

At the plant in New York City a 25,000-gal. unit was in operation for several months and was very thoroughly tested by several chemists, sanitary and electrical engineers. The results were so satisfactory that a 500,000-gal. unit was built and has been in continuous operation since early in April. During this time an average of about 750,000 gal. of sewage has been treated daily, although the unit was constructed for 500,000 gal. For about three months after it was installed, tests were carried out almost continuously by the author, in conjunction for most of the time with Prof. William P. Mason, Dr. C. O. Mailloux and Mr. P. M. Travis. Dr. Mailloux made most of the electrical observations and deductions, while the chemical and bacteriological tests were made by Professor Mason, Mr. Travis and the author, assisted by Mr. William H. Ulrich. The work involved the taking of about 200 samples and their chem-

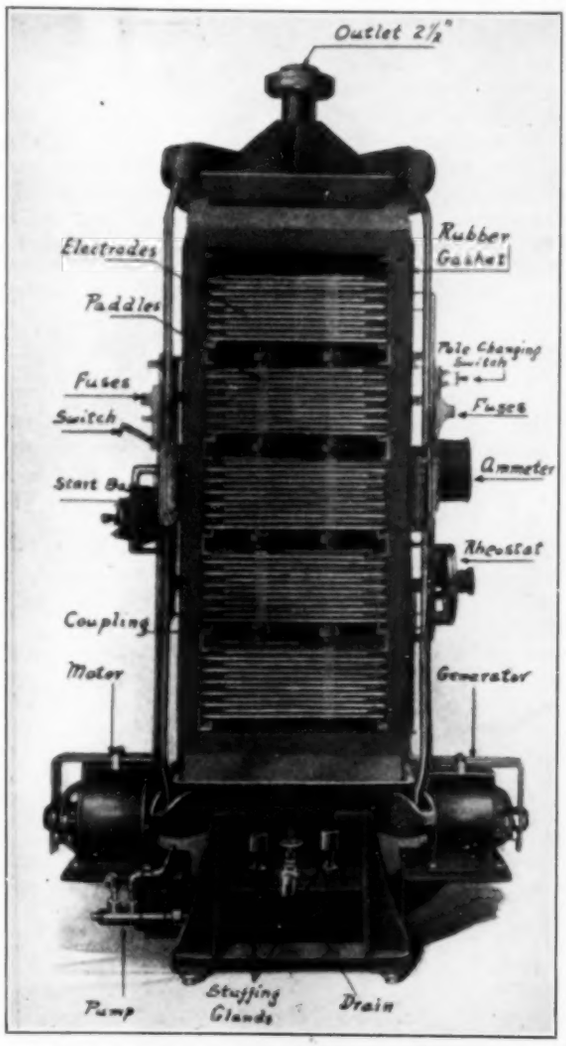

FIG. 1—ELECTROLYTIC APPARATUS WITH DOOR REMOVED, SHOWING ELECTRODES AND PADDLES

*A paper read at the Los Angeles meeting of the American Institute of Chemical Engineers, in joint session with the Southern California section of the American Chemical Society.

ical and bacteriological analyses as well as a very large number of observations of current consumption.

The process and apparatus used was invented and patented by Mr. C. P. Landreth of Philadelphia and will, no doubt, become known as the Landreth electrolytic process of sewage disposal. The electrical purification of sewage has been attempted before in various ways and is or has been in use at a number of localities notably Oklahoma City, Okla., and Santa Monica, Cal.

Mr. Landreth's process seems to be new in that he uses lime together with electrolysis for the treatment of sewage and also in that he uses a much smaller quantity of electricity per gallon than others have employed.

Electricity alone has been used before as well as lime alone, but the combination of these two agents accomplishes what neither of them alone can effect. The Landreth process also employs a very thorough system of agitation.

The process as in use at Elmhurst comprises the following principal stages of operation: (1) screening; (2) electrolytic treatment with addition of lime; (3) sedimentation; (4) filter pressing of sludge.

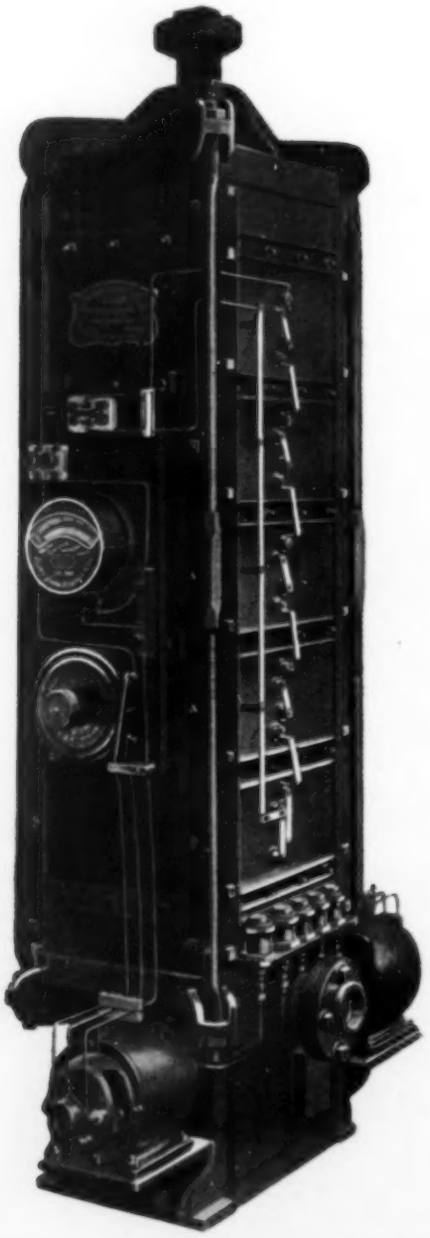

FIG. 2—OUTSIDE VIEW OF ELECTROLYTIC APPARATUS 25,000 UNIT

The raw sewage is delivered by the mains into a receiving well from which it is pumped through quarter-inch screens by means of a centrifugal pump through the electrolytic machine.

The electrolytic machine consists of a horizontal wooden box 23 ft. 3 in. long, 3 ft. in width, and 2 ft. 8¾ in. in depth. It rests upon a masonry foundation 18 in. high. The sides, top and bottom of the box are stiffened by means of angle irons. The top of the box is in two equal sections bolted on, the joint being made tight with a rubber gasket. The top may be removed for cleaning or for the inspection of the electrolytic apparatus.

A series of valves at the bottom serve to remove any sludge which may accumulate in the box.

The sewage to be treated is forced through the apparatus by the pump which takes it from the receiving well and delivers it to the inlet of the apparatus at one end. In passing from the inlet to the outlet (at the other end) of the apparatus, the sewage flows between numerous plates which are placed parallel and close to each other inside the closed box. Consequently the liquid does not flow in one mass, but is subdivided into a large number of relatively thin "sheets." The plates which separate these sheets of sewage from each other also serve as electrical conductors or "electrodes" by means of which electrical currents capable of producing electrolysis are conveyed across the liquid sheets, through the sewage with the result that one side of each liquid sheet is in contact with an "anode" surface, and the other with a "cathode" surface. To insure thorough agitation of the sewage, as it flows in the spaces between the electrode plates, mixers in the form of paddles placed between these plates are rotated in the plans of each liquid sheet.

The plates inside the apparatus are all in a vertical plane, parallel with the sides of the tank, so that the "liquid sheets" of flow between the plates are all vertical. These liquid sheets are not continuous from the inlet to the outlet ends of the apparatus, because the plates are arranged in groups with spaces left between them.

The plates are of iron, and are all of the following dimensions: length, 16 in.; height, 10 in.; thickness, from ¼ in. to 3/16 in. The plates are grouped and assembled in sets, like the plates for an "element" or cell of a storage battery. The plates in each group are all parallel to each other, and they have equal spaces between them (5/16 in. to ⅜ in.). They are held together by bolts, which pass through all the plates, and through the insulating separators between them, and clamp them into a solid unit.

When the groups are in position in the tank, these bolts extend across the tank horizontally and support the plates, which are then all in a vertical position, parallel with the sides of the tank, and occupy the entire available space across the tank. A group contains fifty plates (except in a few cases where the number is one or two less). There are groups at eleven places or divisions in the tank between the inlet and the outlet; and there are two groups at each place, one above the other.

This makes a total of twenty-two groups and (nearly) 1100 plates.

The two bolts just mentioned are also utilized as electrical terminals and conductors for the plates. This is done by insulating the even-numbered plates from one bolt and connecting the odd-numbered plates with it, and doing the opposite for the other bolt.

This is the arrangement used for the groups in the

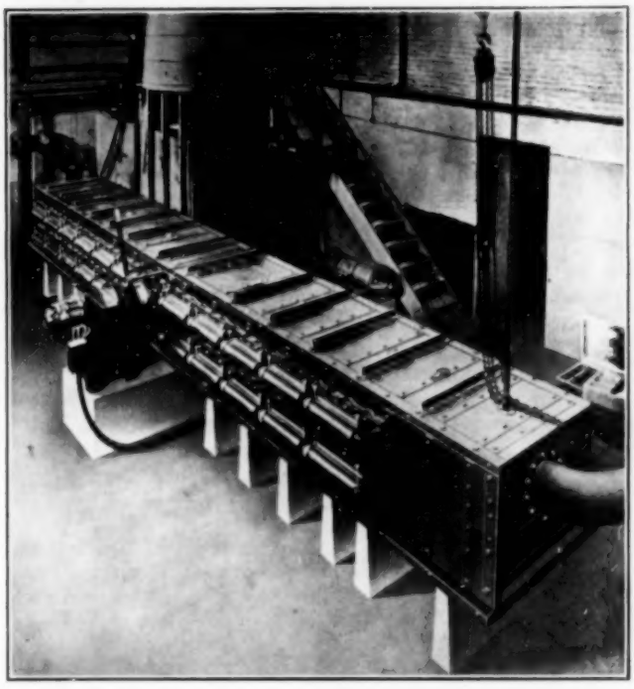

FIG. 3—HORIZONTAL ELECTROLYTIC APPARATUS 500,000 UNIT INSTALLED AT ELMHURST, NEW YORK CITY, MOTOR AND REDUCTION GEARING FOR THE MECHANICAL STIRRERS SHOWN ON LEFT-HAND SIDE OF MACHINE

first section (counting from the inlet) and in the last six sections, or for a total of fourteen groups. In these groups the plates constitute, in each case, an "electrolyzing element" of twenty-five pairs of plates.

In the other four divisions the arrangement is less simple. The fifty plates of each group are not electrically grouped and connected into a single element of twenty-five pairs of plates, but into three elements, each of eight pairs (or more), which are connected in series. It follows that the total number of "elements" in these four sections is twenty-four (*i.e.*, twelve for the four upper groups and twelve for the four lower groups). Adding these to the fourteen elements in the other divisions, the total is thirty-eight elements.

In most of the tests the thirty-eight elements were all connected in a simple series; in one test the nineteen elements in the upper tier were connected by themselves in series, and likewise the nineteen elements in the lower tier; and the two series were then connected in multiple. Various other combinations of series and multiple connection may be made and were made in some of the tests.

When all the thirty-eight elements are connected in series, there is a difference of three to one in the current density at the "large" elements (composed of twenty-five pairs) and at the "small" elements (composed of eight pairs). The same current passes (theoretically) through all the elements, and as the electrode surface is three times greater at the large elements than at the small elements, the current per unit of surface will be only one-third as great at the large elements as at the small elements.

SOURCE OF CURRENT

The current supply required for producing electrolysis is obtained from a direct-current generator of 5-kw. capacity, which is direct driven by an alternating-current induction motor.

The maximum current capacity of the generator is

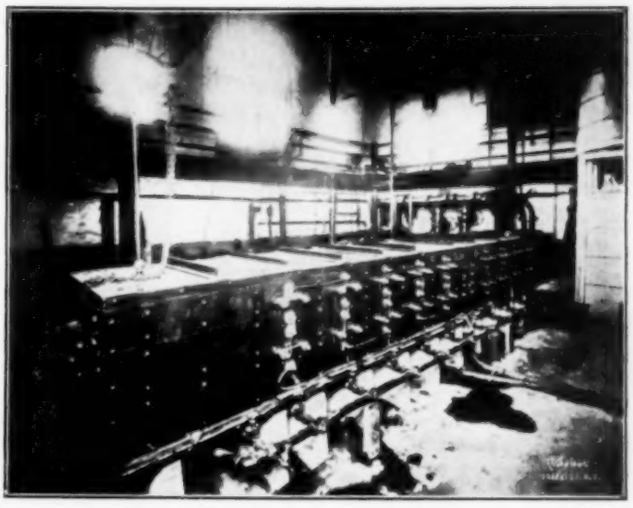

FIG. 4—HORIZONTAL ELECTROLYTIC APPARATUS INSTALLED AT ELMHURST, SHOWING ELECTRICAL CONNECTIONS ON RIGHT-HAND SIDE OF MACHINE

40 amp. and its maximum voltage is 125 volts. A watt-hour meter was especially connected in the mains between the generator and the switch board for the purpose of the test to enable the direct-current output in watt-hours to be computed for given periods of time in connection with the test.

AGITATION OUTFIT

In addition to the two holes in the electrode-plates for the bolts which serve to hold them together there are two other holes which make openings for the shafts upon which the paddles rotating in the spaces between the electrode-plates are mounted. There are two rotating shafts passing through each group of plates, and each shaft carries forty-nine paddles. This makes ninety-eight paddles per group of plates, or a total of 2156 paddles for the twenty-two groups. The forty-four shafts are supported in bearings mounted in the sides of the tank. They pass through the side of the tank, and are driven by bevel gearing from four horizontal shafts, which receive power from a 3-hp. induction-motor through reduction-gearing.

There is a double reduction-gear by which the speed of the clutch-shaft is reduced to seventy-eight when the motor speed is 1800. The horizontal shafts are geared to run at half this speed, and the paddle shafts are geared to run at half the speed of the horizontal

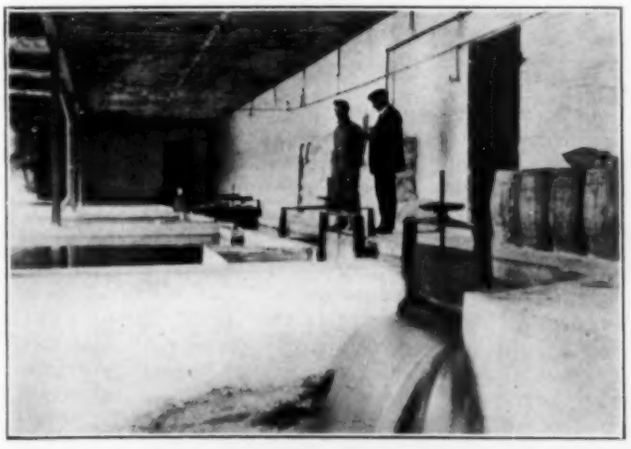

FIG. 5—SEDIMENTATION TANKS AND OVERFLOW OF PURIFIED SEWAGE

shafts. Hence, if the motor ran without slip the paddle shafts would have a speed of 19.5 r.p.m. Actual test showed that the speed of the paddle shafts was from 18 to 19 r.p.m., according to the "load" on the motor, which at times appears to be relatively heavy, as indicated by the rise of temperature of the motor. The increase in load appears to be due to increased friction between the paddles and the electrode plates, owing to deposits on the plates.

The amount of flow of sewage through the machine was measured by a Venturi indicating and recording meter connected in the discharge pipe leading from the machine to the sedimentation tank.

The milk of lime added to the sewage is prepared by putting quick-lime or hydrated lime in a vat with water and agitating the mixture by electric power, produced by a ½ hp. motor. The electric current supply required for operating the pump motor, the lime vat motor and the motor generator is taken from the street mains through watt hour meters.

METHOD OF OPERATION

The milk of lime is introduced into the sewage in several different ways. A small centrifugal pump operated by an electrical motor was at times used to force the milk of lime into the inlet of the electrolytic machine through a suitable pipe, the amount of flow being regulated by a valve on this pipe. A pipe was also provided by which the milk of lime could be forced into the sewage at the outlet of the machine.

The milk of lime was also at times forced into the sewage through a pipe leading to the inlet of the sewage pump. In the latter case the mixture of the milk of lime with the sewage was affected by the action of the pump.

The electrolyzing current was maintained as nearly constant as practicable, the voltage of the direct-current generator being regulated at the switchboard whenever any variation in the current is observed. The "polarity" of the current was reversed about every hour, with the object of equalizing any chemical action that may be produced on the iron electrodes, and preventing the formation of deposits there. A very considerable drop in voltage occurred on reversing the polarity after which the voltage increased again and after about 15 min. was again normal. The volume of electrical current (amperes) sent through the apparatus, varies with the mode of connection of the electrodes. With all the thirty-eight elements connected in simple series, the current through the circuit was generally maintained at about 30 amp. This is the way in which the apparatus has been principally operated.

On one occasion, the elements in the upper and lower tiers were respectively connected in series, and the two series were connected in parallel. This would give nineteen elements in series, each element being composed of two elements in multiple. The current passing through these series on that occasion was maintained at 40 amp., which was the limit of current output of the direct-current generator.

The voltage of the generator must be equal to the sum of the "voltage-drops" at all points in the entire working circuit, including the leads, the electrolyzing elements, and their connections. The voltage-drop at the electrolyzing elements is the factor which, multiplied by the current (amperes) passing through the elements, gives the electrical energy expended directly upon the liquid. The voltage, or potential difference, per element, depends upon the counter-electromotive force, and the polarization incidental to the electrolysis produced, and upon the electrical resistance of the liquid. These conditions, in turn, depend and are affected by the chemical constitution, the density ("strength"), and the temperature of the liquid.

Theoretically the voltage per element should be the same for all sets of electrodes of the same kind (*i.e.*, having the same number and size of plates, etc.), under the same working conditions. Practically, it is found that the voltage per element varies even with plates of the same kind and size, in consequence of changes in the conditions. Deposits are produced on the plates, which alter the amount of active surface of the electrodes, or decrease the thickness of the sheet of liquid flowing between the plates; and chains and bridges of solid matter may at times form between plates of opposite polarity, causing the current to be shunted in part or even short-circuited entirely. Tests made while the apparatus was in operation show that the voltage per element varies appreciably from such causes.

ELECTROLYTIC ACTION PRODUCED PER UNIT VOLUME OF SEWAGE TREATED

The total quantity of electric current sent through a unit volume of the sewage passing through the machine depends (a) upon the total volume of current or the aggregate sum of the electric currents passing through the elements and (b) the speed of flow of the liquid to the apparatus.

The total quantity of current is equal theoretically to the product of the number of elements connected in series by the current in amperes passing through the series. Thus, with a current of 30 amp. passing through all the thirty-eight elements in series, the total quantity of current would be equal to 1140 amp. on the assumption that there is no loss by leakage or shunting past any of the electrodes in the middle portion of the series.

The length of time that the liquid is subjected to electric action depends upon the length and sectional area of the path through which the sewage flows in passing through the apparatus and the rate of pumping, or the speed of flow through the apparatus.

The time of flow through the apparatus, when in operation, under given actual conditions, was determined by injecting a coloring substance into the liquid at some point ahead of the inlet, and then noting the time which elapsed until the color appeared at the outlet of the apparatus. It was found that when the speed of flow through the apparatus (as indicated by the Venturi flow-meter) was at the rate of 765,000 gal. per day, the time of flow through the apparatus was 1 min. 8 seconds, or 68 seconds. Allowance should be made for the time elapsing while the liquid is passing through the inlet and outlet, and through portions of the apparatus at which there are no electrodes. The actual time that the liquid was passing through the machine did not probably exceed 1 min. (60 seconds).

A rate of flow of 765,000 gal. per day is equal to 531.2 gal. per minute. Allowing for 10 per cent leakage, a current of 1140 (or 1026 net) amperes acting during 1 min. represents 61,560 coulombs. The quantity of electric current applied, in 1 min., to the liquid, is

$$\frac{61{,}560}{531.2} = 116 \text{ coulombs per gallon.}$$

This quantity will obviously vary inversely with the rate of flow. Thus, if the rate of flow were increased to 1,000,000 gal. per day, the coulombs per gallon would fall down to 88; and if the rate of flow were decreased to 600,000 gal. per day, the coulombs per gallon would increase to 148. Under these conditions, and taking into account all causes of variation, the quantity of electric current per unit volume of sewage treated may range, in round numbers, between 80 and

150 coulombs per gallon, or 21 to 40 coulombs per liter. In the tests actually made, the electric current ranged between 19.5 and 40.9 amp. according to connections and other conditions of the tests; and the current per unit volume was from 85 to 169 coulombs per gallon (22.5 to 44.7 coulombs per liter). When extreme and unusual conditions are excluded, the figures are likely to remain within the limits just mentioned.

This quantity of electricity will, theoretically, liberate from 0.00174 to 0.00332 grams or 1.21 to 2.31 cu. centimeters of oxygen per liter of sewage treated.

CURRENT-DENSITY

In fourteen sets of electrode-plates all the plates of the set (forty-eight to fifty in number) are connected electrically so as to make one single electrolyzing element of twenty-four (or twenty-five) pairs of plates. In the other eight sets the plates are connected electrically so as to constitute three electrolyzer elements of eight pairs of plates, and the three elements are connected in series. The theoretical active electrode surface in the "single" elements (of twenty-four pairs) is three times greater than in the "triple" elements (of eight pairs). Hence, with the same current passing through "single" and "triple" electrodes (as when they are connected in single series) the current-density in amperes per square foot of active electrode surface, is only about one-third as great at the "single" as at the "triple" electrolyzer elements.

Each electrode-plate is 16 in. in length and 10 in. in height which gives an active surface of 160 sq. in. on each side, from which must be deducted the loss of active area due to holes in the plates (for the shafts on which the "paddles" are mounted) and to insulating separators. An allowance of 10 sq. in. is made for this deduction, which leaves 150 sq. in. per side. Both sides of each plate are active, except at the two outside plates, which have only one active surface. The active surface of the larger electrolyzer elements (of twenty-four pairs of plates) is $23\frac{1}{2} \times 300$ or 7050 sq. in., equivalent to 48.9 sq. ft. The active surface of the smaller electrolyzer elements (of eight pairs of plates) is $7\frac{1}{2} \times 300$, or 2250 sq. in., equivalent to 15.6 sq. ft.

When all the electrolyzer elements in the apparatus (C-24) were connected in series (making thirty-eight in series), the electrolyzing current is maintained at about 30 amp. The maximum current capacity of the direct-current generator is 40 amp. With an electrolyzing current of 30 amp., the current-density will be equal to the following values:

For large units:
30/7050 = 4.25 milli-amp. per square inch, or,
30/48.9 = 0.61 amp. per square foot.
For small units:
30/2250 = 13.33 milli-amp. per square inch.
30/15.6 = 1.92 amp. per square foot.

With 40 amp. these values would be one-third greater.

For large units:
40/7050 = 5.67 milli-amp. per square inch.
40/48.9 = 0.82 amp. per square foot.
For small units:
40/2250 = 17.8 milli-amp. per square inch.
40/15.6 = 2.56 amp. per square foot.

The range of variation of current-density in round numbers is within the following limits:

For large units:
From 4 to 6 milli-amp. per square foot.
From 6/10 to 8/10 amp. per square foot.
For small units:
From 13 to 18 milli-amp. per square foot.
From 1.9 to 2.6 amp. per square foot.

SEDIMENTATION

In the operation of the process, two sedimentation tanks are used. The sewage, after it has passed through the machine (or through the by-pass, if that be used), is discharged into a flume about 3 ft. wide, which connects with the inlet of the sedimentation tanks in the tank room.

After the sewage has received its dose of lime and has been electrolyzed in the machine, it is passed through the above-mentioned flume in a stream, about 6 in. deep, into two settling tanks (each 82 ft. 6 in. x 20 ft. x 5 ft. 3 in., of about 65,000 gal. capacity, and provided with a baffle at the center rising from the bottom, and also with a deep hanging baffle at the entrance and a skimming baffle at the exit, and from the second of them the settled effluent is finally discharged). These tanks are connected in tandem. The sewage enters the first tank at one end and passes through a gate into the second tank at the farther end. The time for sedimentation in each tank is nearly two hours or four hours for total time of sedimentation, dependent upon the rate of sewage flow. The effluent is discharged from the second tank through a flume by which it is conveyed to the discharge pipe.

It is proper to note that these sedimentation tanks were constructed for sewage disposal by the septic process previously in use at Elmhurst. Suggestions have been made for a new type of sedimentation tank and a model embodying some of them has been constructed, with which it is expected that more rapid and perfect sedimentation will be obtained.

FILTER PRESS

Pipe connections of suitable diameter, leading from the bottom of the sedimentation tank, serve to convey the sludge to a receiving basin in the press room whence it is pumped to the filter press, which is of the Johnson type. Attention should be called to the fact that the filter press is not an essential part of the apparatus as other methods of disposing of the sludge may be adopted.

(*To be concluded in issue of Nov.* 1.)

Alloy Steels*

BY GEORGE L. NORRIS

Steel can broadly be defined as an alloy of iron and carbon that can be forged and rolled. From expediency and necessities of manufacture, certain impurities beneficial or otherwise are present, but not in sufficient amounts to materially alter the characteristics of the pure alloy of iron and carbon.

Under this definition, steel, or as it is now often referred to, carbon steel, is usually within the following maximum composition: Carbon, 1.50 per cent; manganese, 1 per cent; silicon, 0.35 per cent; phosphorus, 0.05 per cent; sulphur, 0.05 per cent.

An "alloy" steel is alloyed with one or more metals, in sufficient amounts to influence or change the characteristics of steel, and still possible of forging or rolling.

The usual steel alloying metals are manganese, silicon, nickel, chromium, tungsten, and vanadium. As these metals will all alloy with each other, it is evident that it is possible to obtain a great variety of alloy steels.

Steel containing upward of 1.50 per cent manganese is not commonly considered an alloy steel, although this

*A paper read before the International Engineering Congress in San Francisco, on Sept. 21, 1915, as part of the Symposium on Iron and Steel, arranged and edited by Prof. Henry M. Howe.

percentage of manganese undoubtedly has some effect on the characteristics of steel. This is due no doubt to the fact that manganese is always present in steel.

The alloy steels are usually divided into two groups: "ternary" steels, with one metal alloyed, and "quaternary" steels, with two metals alloyed. The more complex alloy steels are practically limited to high-speed tool stees.

The general characteristics of alloy steels are high elastic limit and great strength, combined with a high degree of toughness, as compared with the carbon steel with which they are alloyed. The strength and hardness can be enormously increased by heat-treatment (quenching and tempering) and still have the steel retain great toughness.

Alloy steels are not as a rule placed in service in the condition as forged or rolled. The forging and rolling temperatures are usually so high that the steel requires heat-treatment to refine the grain and develop the exact combination of strength, hardness and toughness desired. It is frequently necessary to anneal after forging in order to facilitate machining operations. This, of course, necessitates subsequent heat-treatment.

Most of the alloy steels are of medium or low carbon content. The corresponding simple or carbon steels are only slightly or moderately improved in strength by heat-treatment.

The use of alloy steels in cutting tools dates back nearly a hundred years, although it was not until after 1850 or 1860 that alloy steels for this purpose became firmly established.

With the advent of iron-clad warships began the struggle for supremacy between projectile and armor plate that has been so fruitful in the development of alloy steels. Chromium, nickel, and nickel-chromium steels are largely the result of this struggle.

The publication in 1888 by Hadfield of the results of an extensive research of the alloys of manganese and steel, which resulted in the discovery of a remarkable new alloy steel, marks a period of active investigation into the effect of other metals on steel. The most important of these were the investigations on nickel steels by James Riley in 1889, which demonstrated that a mild open-hearth steel, such as used for structural, general forging and machinery purposes, when alloyed with 3 per cent to 4 per cent nickel had considerably higher elastic limit and tensile strength, with practically the same or greater ductility. One of the earliest and most extensive applications of nickel steel was for armor plate. For many years nickel steel was the principal alloy steel in use.

During this same period referred to, Hadfield made investigation of the effects of silicon on steel, and also a very complete study of chromium steels, which for some time had been used in a small way for springs and special forgings, but principally for tools and armor-piercing projectiles.

The development of high-speed steel about 1900, making it possible to readily machine heat-treated alloy steels, and the advent of the automobile with its demand for superior steel, have brought about the present extensive use and development of alloy steels.

The automobile industry, with its demand for steel of high strength and durability, has been undoubtedly the most important factor in the development of commercial alloy steels, and the largest consumer. Alloy steels are used extensively for transmission gears, and shafting axles, steering levers and spindles, springs, chassis frames, crank shafts, cam shafts, connecting rods, valves and many other parts of automobiles.

They are also extensively employed in forgings for high-speed engines, marine engines, locomotives, electrical machinery, mining machinery, and other mechanical engineering structures.

The use of alloy steels in bridge construction has been limited, but there is undoubtedly a field in long-span bridges for an alloy steel of high strength that can be used in the condition as rolled, preferably, or at most with a simple annealing.

Coincident and having a marked influence on the development of alloy steels, was the discovery of large deposits of vanadium ore in Peru, thus assuring a source of supply at a reasonable cost of this rare metal, which is the most powerful yet discovered for alloying with steel, that is, in small amounts.

The most important of the engineering or constructural alloy steels are those containing nickel, chromium, and vanadium, singly or in combination. With all these steels it is possible, through heat-treatment, to obtain a tremendous range in strength, in round numbers varying from 100,000 to 250,000 lb. per square inch, depending also, of course, upon the size of the section.

It is not possible nor within the province of this paper to go deeply into the technology of alloy steels, but only to briefly describe the principal alloy steels and their characteristics.

MANGANESE STEEL

This steel usually contains 10 per cent to 13 per cent of manganese and approximately 1 per cent of carbon. It is practically non-magnetic and has a peculiar hardness, to which it owes a remarkable resistance to abrasion. It is extremely difficult to machine. It has high strength and toughness, but relatively low elastic limit. With care it can be forged and rolled.

It has found its principal application in castings for crushing and grinding machinery and railroad crossings.

Manganese steel has the peculiar property of being toughened and softened by quenching in water, resembling copper in this respect. All manganese steel castings are subjected to this treatment to remove brittleness.

SILICON STEEL

There are two types of silicon steel, one of which has found some application as an engineering steel. This steel, frequently called silico-manganese steel, is generally covered by the following limits of composition: Carbon, 0.45 per cent to 0.65 per cent; silicon, 1.50 per cent to 2 per cent; manganese, 0.50 per cent to 0.80 per cent.

The manganese is normal, contrary to what is indicated by the name. The principal application of this steel is for automobile springs, and to some extent for gears. It fibers readily through heat-treatment, and is very brittle in the direction at right angles to rolling. It is very sensitive to heat-treatment, and a relatively small variation in annealing temperature after quenching has a strong effect on the results obtained.

The other type of silicon steel contains 3 per cent to 5 per cent silicon, is low in carbon and manganese, and is extensively used for electrical transformer sheets on account of its high permeability and electrical resistance. Structurally, it is weak and has no constructural value.

NICKEL STEEL

Nickel alloys with steel in all proportions, but by far the most important nickel steel, from an engineering standpoint, is the low- and medium-carbon steel with 3 per cent to 4 per cent of nickel, commonly known as 3½ per cent nickel steel.

The presence of manganese in nickel steel is very essential, as it has a marked effect on the mechanical properties. The amount of manganese should range from 0.50 per cent to 0.80 per cent.

This steel has been extensively used since its introduction in 1889, and is a good all-round engineering and structural steel with considerably higher elastic limit and tensile strength than the corresponding carbon steel, and with practically the same degree of ductility.

The low-carbon steel, 0.10 per cent to 0.20 per cent, is used extensively for case-hardening parts. It case hardens more readily than carbon steel and gives a harder casing with a strong, tough, fibrous core.

A great deal of nickel steel with carbon from 0.20 per cent to 0.35 per cent has been used in shapes and plates as rolled and in annealed eye-bars for bridge construction. In this condition, which is not to be recommended for forgings, the following are typical physical properties.

Elastic limit, lb. per sq. in.	45,000 to 60,000
Tensile strength, lb. per sq. in.	80,000 to 100,000
Elongation in 2 inches, per cent	20 to 15
Reduction of area, per cent	40 to 25

Annealed nickel-steel forgings have only slight advantage in strength over carbon steel, and consequently are not advantageous either from an engineering standpoint or commercially unless heat-treated. With heat-treatment it gives considerably higher strength than carbon steel, combined with greater ductility or toughness. It does not give as high values as the nickel chromium and chromium-vanadium steels.

Nickel steel rolls and forges readily and machines easily. It develops a very thick, hard scale which is apt to give considerable trouble in drop-forging and is hard on the dies. Nickel steel is also very liable to develop seaminess, especially when made in large heats and cast into large ingots, as is now customary. It requires a larger discard to insure soundness. The use of nickel steel in forgings, and particularly drop-forgings, is falling off in favor of other alloy steels with greater values.

CHROMIUM STEEL

The use of this steel is confined principally to a few specialties and it is not in general use as an all-round engineering steel. One of the principal uses is for balls and ball races. The great mineralogical hardness obtained by quenching is very desirable for this purpose. The steel for this application contains approximately 1 per cent each of carbon and chromium.

Chromium steel is also used for stamp-mill shoes, and in combination with soft steel in laminated plates for construction of burglar-proof safes, and in the same combination in bars for jails.

The low- and medium-carbon types, containing 0.80 per cent or less of chromium, have somewhat higher mechanical properties than the corresponding carbon steel. It is not used to any great extent, other alloy steels being superior, both in static and dynamic strength. Chromium steel is also very liable to crack and check in heat-treatment.

NICKEL-CHROMIUM STEEL

The addition of chromium to nickel steel has a marked effect, greatly increasing the strength and resistance to shock and particularly the mineralogical hardness. It is more difficult to forge and heat-treat and harder to machine, and is also liable to the seaminess frequently present in nickel steel. There are three types of this steel, differing both in the percentage of nickel and chromium, and all with low or medium carbon:

	Nickel, Per Cent	Chromium, Per Cent	Carbon, Per Cent
1st	3.5	1.50	0.25 to 0.45
2d	2.0	1.00	0.10 to 0.45
3d	1.5	0.50	0.10 to 0.45

The first type is used principally for armor plate and armor-piercing projectiles and came into use about 1895, superseding the nickel plates and chromium projectiles.

The other two types were developed by the automobile industry. The second type is largely for automobile forgings. It gives high strength with heat-treatment, has great hardness and good shock and fatigue resisting qualities.

The third type is a largely used all-round engineering steel. It is used for automobile forgings and for a variety of miscellaneous drop-forgings and machine parts. It is an excellent case-hardening steel, carbonizing readily. This type is more tractable in working, heat-treating and machining than the other two. It is also somewhat lower in tensile strength.

VANADIUM STEEL

The addition of small amounts of vanadium, generally under 0.25 per cent, to simple carbon steel or any of the alloy steels increases very considerably—about 30 per cent or more—the elastic limit and breaking strength, without materially affecting the ductility. To an even greater extent it increases the resistance to shock and fatigue.

The vanadium steel which has been up to now most generally used is a chromium-vanadium steel of the following typical compositions:

Carbon, 0.10 per cent to 0.55 per cent.
Manganese, 0.50 per cent to 0.80 per cent.
Chromium, 0.80 per cent to 1.00 per cent.
Vanadium, over 0.15 per cent.

The lower carbon type, 0.10 per cent to 0.20 per cent, is used mainly for case-hardening and is the best steel for this purpose. It carbonizes readily, gives the highest maximum carbon and finest grain. The casing is very strongly coherent to the core, very hard, tough, and strong, and practically free from any tendency to flake or powder. The core is remarkably strong and tough.

The higher limits of carbon, 0.45 per cent to 0.55 per cent, are extensively used for automobile and locomotive springs, giving remarkable resiliency and endurance. It is also extensively used for oil-tempered gears.

The range in carbon from 0.35 to 0.45 per cent is largely employed for crank shafts, locomotive axles, crank pins, connecting rods, hammer piston rods, automobile transmissions and rear axle shafts.

The range from 0.25 per cent to 0.35 per cent carbon is used for automobile forgings of all kinds and a great variety of miscellaneous work requiring the best combination of static and dynamic strength.

As illustrating the wonderful shock and fatigue enduring qualities of chrome-vanadium steel, drop-hammer piston rods of this material are giving many times the length of service of carbon, nickel, and chromium-nickel steel rods.

Vanadium steels have a much wider heat-treatment range than other steels. The desired physical properties can be obtained with a higher draw-back or annealing temperature, which is very advantageous as more completely removing quenching strains, and also as a manufacturing proposition.

Chromium-vanadium steel forges and machines better than nickel-chromium steel, is not as liable to injury in heating for forging, is not so liable to crack or check in heat-treatment and is free from the seamy tendency of steel containing nickel.

Carbon steel with a small percentage of vanadium, from 0.15 per cent to 0.20 per cent, has been used extensively for locomotive-frame castings with great success. The failure of these frames from all causes over a period of nearly ten years has been only a fraction of 1 per cent.

In tool-steel grades this steel has better cutting qualities, hardens deeper and more uniformly, and has remarkable toughness. In what are termed battering tools, chisels, cutters, dies, etc., it gives several times the length of service of ordinary carbon tool steel.

The handicap of high cost of vanadium has almost disappeared, and simple carbon-vanadium steel in the ordinary forging grades will undoubtedly soon become very widely used as an all-round engineering steel, when a better steel than carbon is required. It is remarkably clean and is as easily worked as carbon steel. It is free from the seaminess and ugly scale of nickel steels and the tendency to check and crack of the chromium steels, particularly nickel-chromium.

Tests of carbon-vanadium steel rails in curves are showing about 20 per cent less wear than rails with 0.15 per cent to 0.20 per cent higher carbon, and are also considerably stronger. This difference in wear will doubtless be much greater when the carbon percentage in the vanadium rails is increased to that of the standard rails.

In simple annealed forgings, plain vanadium steel has physical properties well above those specified for heat-treated (quenched and tempered) carbon steel.

This type of vanadium steel has a wider range of quenching temperature than nickel or nickel-chromium steels; and for mechanical properties after heat-treatment is practically on an equality with 3½ per cent nickel or the low nickel-chromium steels in general use, and apparenty has higher fatigue-resisting qualities.

While nickel and chromium interfere seriously with the welding quality of steel, vanadium does not, but on the contrary improves this quality. Vanadium steel wire is in common use for autogenous welding.

TUNGSTEN STEEL

This is principally used for magnets for magnetos and to some extent in hack saws and special tool steels. Tungsten is seldom used in engineering constructional steels, and then usually in combination with chromium.

Table I shows the typical engineering alloy steels and their tensile properties for the same heat-treatment draw-back temperature. This is in all cases 600 deg. C. (about 1100 deg. Fahr.). The specimens in most cases were heat-treated in the form of inch rounds and were machined after treatment.

Table I.—Typical Engineering Alloy Steels

Carbon, Per Cent	Manganese, Per Cent	Nickel, Per Cent	Chromium, Per Cent	Vanadium, Per Cent	Elastic Limit, Lb. Per Sq. In.	Tensile Strength, Lb. Per Sq. In.	Elongation in 2 In., Per Cent	Reduction of Area, Per Cent
.27	.55	...	...	..	49,000	80,000	30	65
.27	.47	...	...	.26	66,000	98,000	25	52
.36	.42	...	...	..	58,000	90,000	27	60
.34	.87	...	...	.13	82,500	103,000	22	57
.45	.50	...	...	..	65,000	96,000	22	52
.43	.60	...	...	.32	96,000	122,000	21	52
.47	.90	...	...	.15	102,000	127,500	23	58
.30	.60	3.40	...	..	75,000	105,000	25	67
.33	.63	3.60	...	.25	118,000	142,000	17	57
.30	.49	3.60	1.70	..	119,000	149,500	21	60
.25	.47	3.47	1.60	.15	139,000	170,000	18	53
.25	.50	2.00	1.00	..	102,000	124,000	25	70
.38	.30	2.08	1.16	..	120,000	134,000	20	57
.42	.22	2.14	1.27	.26	145,000	161,500	16	53
.36	.61	1.46	.64	..	117,600	132,500	16	58
.36	.50	1.30	.75	.16	140,000	157,500	17	54
.30	.50	...	.80	..	90,000	105,000	20	50
.23	.58	...	.82	.17	106,000	124,000	21	66
.26	.48	...	.92	.20	112,000	137,000	20	61
.35	.64	...	1.03	.22	132,500	149,500	16	54
.50	.92	...	1.02	.20	170,000	186,000	15	45

COMPLEX ALLOY STEEL

Practically none of the constructional steels contain three or more alloy metals. The only steel in this class to be considered is what is commonly known as high-speed steel.

Robert Mushet developed and patented about 1860 an air-hardening steel that was very much superior to carbon steel for machining hard material. Mushet steel, as it was known, had about the following composition:

Carbon, 2.00 per cent.
Manganese, 1.75 per cent.
Silicon, 0.75 per cent.
Chromium, 0.40 per cent.
Tungsten, 5.50 per cent.

At the Paris Exposition in 1900 the Bethlehem Steel Company exhibited a new tool steel that took wonderfully heavy cuts at high speeds, the point of the tool heating up to a strong blue color without losing its edge.

This steel, which immediately became known as high-speed steel, was the culmination of the research work carried on for many years by Mr. F. W. Taylor and later published in his monograph "The Art of Cutting Metals." The difference between this steel and Mushet steel is apparent from the following typical composition:

Carbon, 0.60 per cent.
Manganese, 0.20 per cent.
Silicon, 0.10 per cent.
Chromium, 4.00 per cent.
Tungsten, 18.00 per cent.

With this steel, cutting speeds of over 90 ft. per minute were obtained.

Within three or four years it was found that the addition of vanadium to high-speed steel made it possible to still greatly increase the speed and size of cut. At first only about 0.30 per cent vanadium was added, but this has been increased until now 1.00 per cent is practically the standard amount in most high-speed steels, and speeds of 140 ft. and upward per minute have been attained.

Lately the addition of cobalt to high-speed steel has been meeting with favor as still further improving the endurance of the steel. The amount of cobalt generally used is 3 per cent to 4 per cent, with no change in the percentage of the other metals—tungsten, chromium and vanadium.

Pittsburgh, Pa.

Stearic Acid.—The price of this commodity has increased very materially since the beginning of the European conflict. It is largely used in the manufacture of the highest grades of Tripoli and white finish composition, and forms one of the chief ingredients. Due to its continued advancing tendency, it seems very evident that the price of good Tripoli and lime composition must be increased to meet the increased raw material costs. A movement is contemplated by several of the largest manufacturers of Tripoli composition to form a company and erect a rendering plant for the manufacture of stearic acid (from its tallow basis) and in sufficient magnitude to take care of their own and some outside requirements. This would enable the Tripoli manufacturers to offer the best and most uniform product and at the lowest possible cost. Members of the Metal Finishers Equipment Association, which is primarily interested in the good and standardization of the industry, speak very encouragingly of the project and will no doubt give it their enthusiastic support.

The **Federal Dyestuff & Chemical Co.** has been incorporated in Delaware on Oct. 4 as a $15,000,000 concern of New York. The incorporators are Blair Frazier, Newton James, and George A. Harrington, all connected with White & Co., bankers of 30 Pine Street, New York. Further information is not yet available.

The Co-operative Metallurgical Exhibit at the Panama-Pacific International Exposition

BY A. E. WELLS AND G. H. CLEVENGER

The co-operative metallurgical exhibit forms an important part of the United States Bureau of Mines exhibit at the Exposition and is of particular interest to those connected either directly or indirectly with the metallurgical industry. Although this display appears as a Government exhibit and is directly under the management of the Bureau of Mines, it was only made possible by the generous co-operation of the metallurgical industry and the manufacturers of metallurgical machinery and laboratory apparatus who have contributed the funds and equipment necessary for the installation and operation of the exhibit.

The metallurgical exhibit had its inception with the formation of a committee upon metallurgical participation by Charles E. Van Barneveld, Chief of Mines and Metallurgy. This committee consisted of F. G. Cottrell, pyrometallurgy, G. H. Clevenger, hydrometallurgy, and D. A. Lyon, electrometallurgy. Conditions arose which made it impossible to proceed with the plans of the electrometallurgical section of the exhibit, but the work

FIG. 1—EASTERN FAÇADE, PALACE OF MINES AND METALLURGY

of procuring subscriptions from the mining industry and manufacturers for the hydrometallurgical and pyrometallurgical exhibit was at once proceeded with and met with such a ready and liberal response that it was possible to proceed with the plans for the exhibit without delay.

The object of the exhibit has been three-fold. First, to present an attractive and instructive exhibit which would serve to interest the general public in the metallurgical industry. Second, to bring about a closer relationship between the metallurgical industry and the Bureau of Mines and thus enable the Bureau to most effectively assist the industry in the solution of its problems. Third, to begin and, so far as possible, complete the investigation of certain definite metallurgical problems.

The exhibit occupies about 7000 sq. ft. floor area, directly opposite the north entrance of the Palace of Mines, and is in two sections, the east half of the block being devoted to a working display of hydrometallurgical machinery, while the west half of the block is devoted to working laboratories.

The work in the laboratories is under the general direction of Dr. F. G. Cottrell, Chief Chemist of the Bureau of Mines. The chemical research laboratory is under the direction of Dr. L. H. Duschak, Chemical Engineer of the Bureau of Mines. Pyrometallurgical investigations are under the direction of A. E. Wells, Metallurgist of the Bureau of Mines. The hydrometallurgical research work is under the direction of Professor G. H. Clevenger of Stanford University, Consulting Metallurgist to the Bureau of Mines.

Some of the problems under investigation may be enumerated as follows:

(1) The chemistry of roasting sulphide ores in the presence of water vapor and other gases, with the view of devising means of recovering the sulphur. This investigation is being conducted in both the chemical research laboratory and in a small multiple-hearth furnace in the pyrometallurgical laboratory.

(2) Microscopic examination of slags from copper and lead smelting plant, and investigation to determine the possibility of recovery of the metals from the slag.

(3) Investigation of the chemistry and commercial possibilities of the wet thiogen process for the recovery of sulphur from smelter flue gases.

(4) A preliminary investigation of the mechanism of slime settling.

(5) An investigation of the chemistry of the cyani-

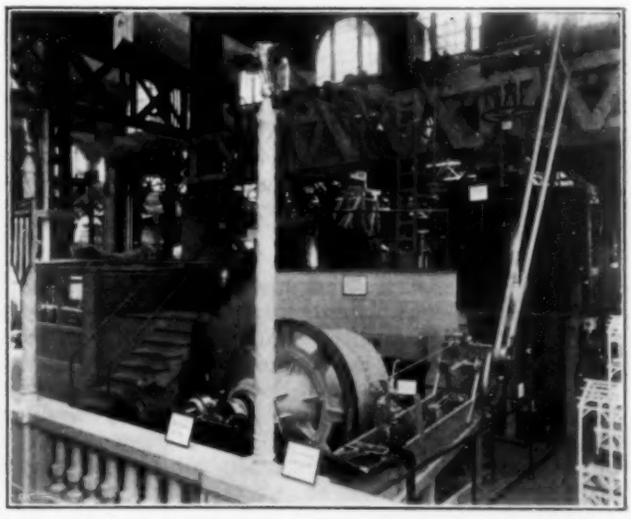

FIG. 2—EXHIBIT OF HARDINGE MILL AND DORR CLASSIFIER AND THICKENER

dation of silver minerals and its bearing upon the treatment of complex silver-gold ores.

(6) Standardization of the methods of analysis and assaying used in hydrometallurgical plants.

(7) The behavior of aluminium compounds in cyanide solutions.

The results of these investigations will be published in the bulletins or technical papers of the Bureau of Mines, and eventually will be available to all who are interested.

Starting at the northeast corner of the block is a model ore sampling mill which is an exact reproduction of the Colorado Springs sampling plant of the Portland Gold Mining Company.

Adjoining this is a 4½-in. Hardinge tube mill, arranged in a closed circuit with a small Dorr simplex classifier. The overflow from the classifier is elevated to a Dorr thickener by means of a Byron Jackson direct-connected centrifugal pump. The overflow from the thickener is returned to the classifier sand and to the tube mill discharge. The underflow from the Dorr thickener is transferred by diaphragm pump to a Dorr agitator.

The pulp, after treatment in the agitator, is pumped by a single stage direct-connected Byron Jackson pump to a Merrill 10-frame, 3 x 4 in., automatic sluicing slime press, where it is washed by solution introduced by the same pump. The press is sluiced by means of a four-stage direct-connected Byron Jackson pump. The clear solution effluent from the press during the filling and washing is delivered by gravity to a 4 x 6 ft. sump tank.

The cloudy solution overflowing from the thickener is delivered by gravity to a second sump from which it is pumped to a Merrill 20-frame 3½ x 3½ ft. automatic sluicing clarifying filter. The clear solution from the clarifying press is delivered by gravity to the sump which received the slime press effluent.

At intervals of from 6 to 8 hr. or more, the deposit on the filter cloths of the clarifying press is removed by sluicing with high-pressure jets of water introduced through a rotating sluicing pipe, this operation being similar to that of sluicing the slime press, except that in the clarifying press the sluicing pipe is located at the center of the plates and frames and rotates in one direction only, whilst in the slime press the sluicing pipe is located at the bottom of the plates and frames and is reciprocated back and forth.

The clear rich solution in the first tank is pumped to a Merrill 10-frame 36-in. agitating precipitation press, the precipitant being delivered into the suction of the pipe between the tank and the pump by a specially designed feeder which can be readily adjusted to feed a varying amount of precipitant. The dry finely powdered precipitant drops from this feeder into a grinding pan or emulsifier, into which is also fed enough water or solution to form an emulsion with the precipitant. The clear effluent barren solution is delieverd to a third sump to be used as a wash for the pulp collected in the slime press. The precipitant is retained in the filter press until it becomes time for a "clean-up."

As it is not feasible to secure a continuous supply of fresh ore in the model cyanide plant, the same pulp is kept in circulation by returning the discharge from the Merrill press to a second Dorr thickener. The overflow from the second thickener is returned to the filter effluent sump, while the underflow is pumped up to the agitator tank by means of a second diaphragm pump. In this way continuous operation is made possible with a minimum amount of material in circulation.

An alternate system of filtration is represented by the Oliver filter. This is the smallest size of standard Oliver filter manufactured, having a drum 3 ft. in diameter by 2 in. in width. A 25 in. to 28 in. vacuum is maintained by a 3½ in. Root rotary wet vacuum pump. Air at 5 lb. pressure from a Baker-Hansen rotary blower is used for the release of the cake and agitation. A 1½ in. Krogh centrifugal pump returns the pulp from the agitator to the Dorr thickener.

This filter is being used in the exhibit for demonstrating the dewatering of flotation concentrate from the Anaconda Copper Mining Company's Washoe plant. The concentrate is fed to the filter from a 4-ft. Dorr thickener at a consistency of one part of water to one part of solids, and is discharged as a ¾-in. cake containing 6 per cent moisture. The discharged cake is carried by belt conveyor to an agitator, where it is broken up and returned to the circuit. In practice this conveyor would probably discharge into a briquetting machine.

The west half of the block is devoted to laboratories, models and charts. In the assaying and general laboratory are installed Braun laboratory crushers, pulverizers, mixers and samples, Abbe ball mill, Tyler Ro-Tap sieve shakers, a complete set of Tyler standard screens, Braun combination gas furnace, gasoline crucible furnace, two muffle assay furnaces for burning crude oil, constant temperature roller agitator, Féry radiation pyrometer, Bristol recording thermometers, and the other accessory equipment necessary in such a laboratory. A balance room, completely enclosed in glass, contains Ainsworth assay and analytical balances and a Keller assay balance. A feature which has proven of unusual interest to the general public in this section is a special chart which shows all the operations of fire assaying.

Adjoining the assay and ore testing laboratory is the pyrometallurgical laboratory. At the present time the equipment of this laboratory consists of the following pieces of apparatus:

(1) A Wedge multiple-hearth roasting furnace, especially designed for experimental work. This furnace has a capacity of 500 lb. of ore per day, and is now being used for experimental work in connection with the distillation of sulphur from sulphide ores, and also for the reduction of barium sulphite and sulphate in connection with an investigation of the thiogen process.

(2) A Monarch tilting furnace. This is being used in connection with the work upon the thiogen process. Bristol indicating and recording pyrometers are used for showing the temperature of the Wedge furnace and the tilting furnace.

(3) A working unit of an electrical precipitation apparatus having a capacity of about 500 cu. ft. of gas per minute. This is complete with transformer, rectifier and precipitation units, and is so arranged that it may be used in conjunction with the experimental Wedge roaster.

(4) A cooling tower, designed by Hunt & Fogg, is being used in connection with the Wedge furnace.

The research laboratory at the other end of the space is surrounded by glass partitions on account of the delicate nature of the work. The experimental work in this laboratory is for the purpose of determining the fundamental chemical principles involved in certain of the metallurgical processes under investigation on a larger scale in the pyrometallurgical and hydrometallurgical laboratories.

The equipment used in this laboratory includes Siemens & Halske indicating and recording pyrometer, a Tycos recording pyrometer and special apparatus designed and constructed in the laboratory. Further equipment includes a complete installation of Leitz micro-metallograph and accessory equipment for microscopic examination of ores, metals and metallurgical products. In connection with this there is also a band saw especially constructed for cutting rock sections, as well as two polishing machines for preparing sections for microscopic examination.

An analytical laboratory, fully equipped with hoods, fume cupboards, gas, compressed air, vacuum and running water, is located adjoining the research laboratory and is used for the analytical work which arises from the various investigations which are being made. Electric furnaces and hot plates of the Electric Heating Apparatus Co. have also been installed.

Facing the main entrance to the exhibit are illuminated charts showing the typical operations of lead and copper smelting. In the same space is a model of an electric precipitation installation, a small working model of a bag house, and also a small model of a Dwight and Lloyd sintering machine. In a glass case is shown a collection of products from both lead and copper smelters, and in another case is shown a complete set of products representative of the Homestake metallurgical practice. Directly back of this space is a small office and conference room.

The funds necessary for the installation and maintenance of the exhibits have been supplied by the following: American Smelting and Refining Company; Anaconda Copper Mining Company; Dorr Cyanide Machinery Company; International Nickel Company; Nevada Mine Operators' Association; Oliver Continuous Filter Company; Phelps-Dodge & Company; Portland Gold Mining Company; the Thiogen Company; W. S. Tyler Company.

The metallurgical Exhibit Fund is deposited with The Union Trust Company of San Francisco, and is administered by the following trustees: F. G. Cottrell, E. B. Braden, Charles E. Van Barneveld, Albert Burch and C. L. Ely.

The following have loaned equipment or donated supplies for the exhibit:

Paul O. Abbe, New York City: Pebble mills, including accessory equipment and cost of installation.

Wm. G. Ainsworth & Sons, Denver, Col.: Assay balance and analytical balances and weights.

Baker-Hansen Company, Oakland, Cal.: Rotary air compressors, rotary vacuum pump, including complete installation.

J. T. Baker & Co., Phillipsburg, N. J.: Laboratory reagents.

Bausch & Lomb Optical Co., Rochester, N. Y.: Microscopes; arc lamp for microscopic work.

Braun Corporation, Los Angeles, Cal., and Braun-Knecht-Heimann Co., San Francisco, Cal.: Laboratory crushers, pulverizers, samplers and mixers, cupel machine, assay furnaces, crucibles, flues and chemicals for assaying, assay chart, roller agitator, apparatus and glassware for ore testing laboratory, including cost of installation.

The Bristol Company, Waterbury, Conn.: Recording and indicating thermometers and pyrometers.

Byron Jackson Iron Works, San Francisco, Cal.: Centrifugal pumps.

Crocker-Wheeler Co., San Francisco, Cal.: Electric motor.

Dorr Cyanide Machinery Co., New York City: Classifier for fine ground ore, continuous thickener, continuous agitator, including accessory equipment and complete installation.

Dwight & Lloyd Sintering Co., New York City: Model sintering machine.

Edison Storage Battery Supply Co., San Francisco, Cal.: Storage battery.

Electric Heating Apparatus Company, New York City: Electric hot plates, electric crucible furnace.

Charles Engelhard, New York City: Recording and indicating pyrometers.

Guernsey & Company, San Francisco, Cal.: American Blower Company exhauster.

Hardinge Conical Mill Company, New York City: Conical tube mill, including complete installation.

H. W. Johns-Manville Co., San Francisco, Cal.: Fireproof cements and asbestos.

Krogh Pump Manufacturing Co., San Francisco, Cal.: Centrifugal pumps.

Keller Manufacturing Co., Salt Lake City, Utah: Assay balance.

Ernst Leitz, New York City: Micro-metallograph and automatic arc lamp, microscopes.

Mammoth Copper Mining Co., Kenneth, Cal.: Operating model of bag house.

Merrill Metallurgical Company, San Francisco, Cal.: Automatically sluiced filter press, automatically sluiced clarifying filter, agitating precipitation filter, zinc dust feeder and emulsifier, including complete installation.

Monarch Engineering Co., Baltimore, Md.: Tilting furnace.

Oliver Continuous Filter Co., San Francisco, Cal.: Continuous filter, including complete installation.

Pacific Tank and Pipe Company, San Francisco, Cal.: Redwood tanks, including installation.

Portland Gold Mining Co., Colorado Springs, Col.: Operating model of sampling mill.

P. H. & F. M. Roots Co., Connersville, Ind.: Rotary vacuum pump.

E. H. Sargent Company, Chicago, Ill.: Water still.

I. C. Smith, Los Angeles, Cal.: Air compressor.

Spencer Lens Company, Buffalo, N. Y.: Microscopes.

H. B. Squires Manufacturing Co., San Francisco, Cal.: Cutler-Hammer air-pressure control apparatus.

Taylor Instrument Companies, Rochester, N. Y.: Féry radiation pyrometer, thread recorder and thermoelement.

W. S. Tyler Company, Cleveland, Ohio: Ro-Tap sieve shaking machine and standard sizing screens.

Union Oil Company of California, San Francisco, Cal.: All fuel oil, gasoline distillate, lubricating oils, used in the exhibit during the Exposition.

Utley Wedge, New York City: Mechanical roasting furnace.

Fred. Ward & Sons, San Francisco, Cal.: Carborundum grinding powder.

Western Precipitation Company, Los Angeles, Cal.: Electrical precipitation apparatus and model of installation.

Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa.: Electric motors.

G. E. Witt Co., San Francisco, Cal.: Pressure reducing valve.

The United States Geological Survey have co-operated through the detailing from their staff of F. B. Laney and E. S. Bastin, who have charge of the microscopic and mineralogical work.

The University of Utah has detailed Prof. R. H. Bradford and Fellow H. J. Morgan to co-operate in the investigations which are being made.

Prof. Welton J. Crook of the South Dakota State School of Mines has contributed his services in connection with some work upon the cyanidation of silver minerals.

The following men have been detailed by the United States Bureau of Mines, largely from the San Francisco Station: G. H. Clevenger, consulting metallurgist; F. G. Cottrell, chief chemist; L. H. Duschak, chemical engineer; W. Freeman, junior chemist; R. E. Head, skilled laborer; G. N. Libby, assistant metallurgist; A. E. Wells, metallurgist; E. H. Zeitfuchs, junior chemist.

The following men have been employed with the co-operative fund: C. E. Brandt, analytical chemist; R. Buhman, assistant chemist; H. S. Coe, assistant metallurgist; H. B. Jordan, assayer; G. A. Linhart, analytical chemist; E. A. Madison, draughtsman; E. I. Oberlightner, laborer; K. Pyle, assistant metallurgist; H. W. Young, assistant metallurgist.

Graphite brushes for use upon commutators are being furnished by the Joseph Dixon Crucible Co. of Jersey City. It has been found that they are free from grit and are self-lubricating.

Transvaal Gold Production.—The number of companies reporting to the Transvaal Chamber of Mines in March, 1915, was 63. The total quantity of ore milled during that period was 2,123,465 tons. There were 9745 stamps in operation, with an average duty of 9.22 tons per 24 hours. Tube-mills in commission numbered 309. The yield for the month was 676,221 fine ounces gold. The working profit per ton milled was only 8s. 4d., as compared with 9s. in February, 1914.

Vulcanized Fibre

BY CHARLES ALMY, JR.

Despite the fact that the annual production of Vulcanized Fibre in this country exceeds 15,000,000 lb., comparatively little is known either of the method of manufacture or the properties of this widely used material. Books on Industrial Chemistry or Cellulose Products, as a rule, dismiss the subject with a few words, often inaccurate or misleading, and give in many cases the impression that Vulcanized Fibre is still largely in a visionary stage, interesting chiefly from the theoretical standpoint.

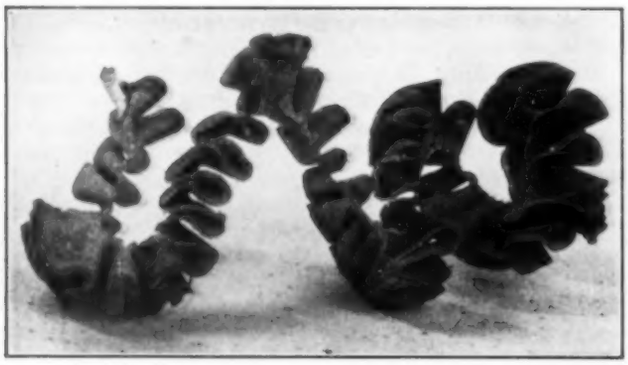

FIG. 1—MACHINE TURNING OF VULCANIZED FIBRE SHOWING ITS TOUGHNESS

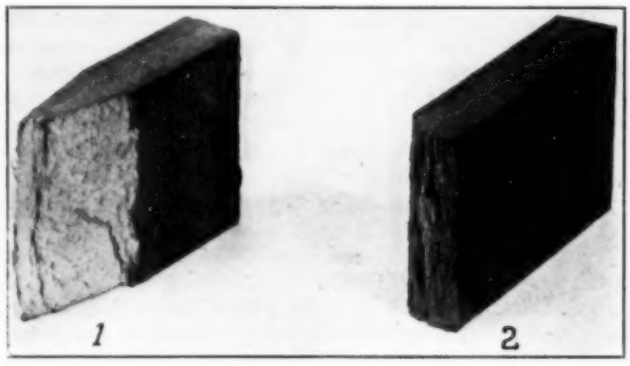

FIG. 3—TENSILE TEST—NO. 1, SP. GR. 1.25, FRACTURED AT 8650 LB. PER SQUARE INCH—NO. 2, SP. GR. 1.37, FRACTURED AT 12,250 LB. PER SQUARE INCH

The purpose of this brief article is to explain in a few words the main facts regarding its manufacture and to outline some of the properties that have made it so widely useful to the engineering professions.

Vulcanized Fibre was invented by an English chemist named Taylor about the year 1869, but its commercial development dates from 1873 when the American Vulcanized Fibre Company was established in Wilmington, Del. Although the original patents included the use of sulphuric or nitric acids with or without the addition of various metallic salts, the process as practised to-day is confined to the action of zinc chloride on an all cotton cellulose paper, unsized and unloaded.

This paper is passed over heated cylinders through a bath of zinc chloride maintained at about 70 deg. Baume and 40 deg. C., depending upon the quality of the paper and the atmospheric conditions. It is then rolled up over large heated drums to the desired thickness, the zinc chloride hydrolyzing the cellulose and gelatinizing the surface to such an extent that the paper unites together and forms an almost homogeneous mass. Fibre tubes are made in a similar manner by substituting for the large drums, mandrels of the proper size to give the desired inside diameter.

The "green fibre" is then washed in zinc chloride baths of progressively diminishing concentration until it is commercially pure, i.e., contains less than 0.15 per cent chlorine. This process is of necessity very slow, and any attempts to expedite it are apt to result in an inferior grade of fibre or in blisters due to the increased osmotic pressure. One-quarter inch fibre, for instance, requires three to four weeks for washing, and 2-in. fibre six to eight months. The wet pure fibre is dried at a temperature of 40 deg. to 60 deg. C., after which it is pressed and usually calendered.

The finished product which has shrunk to one-half its original thickness is a homogeneous, tough, horn-like material which can be readily machined, threaded, embossed, etc., and which can be given a high polish. Fig. 2 shows cross sections of two pieces of gray vul-

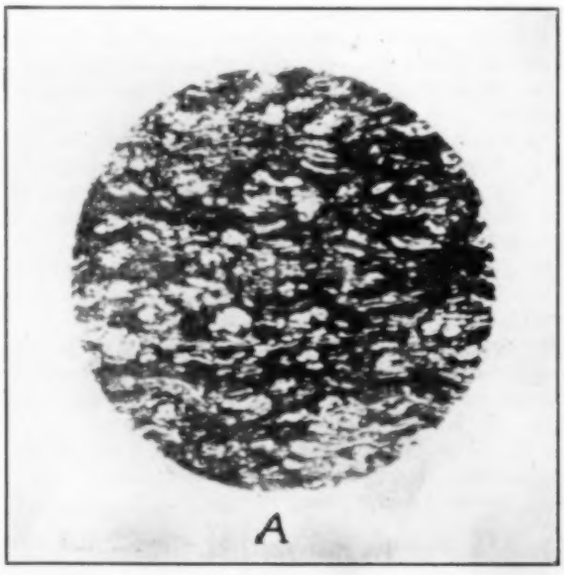

FIG. 2A—GRAY VULCANIZED FIBRE, SP. GR. 1.45

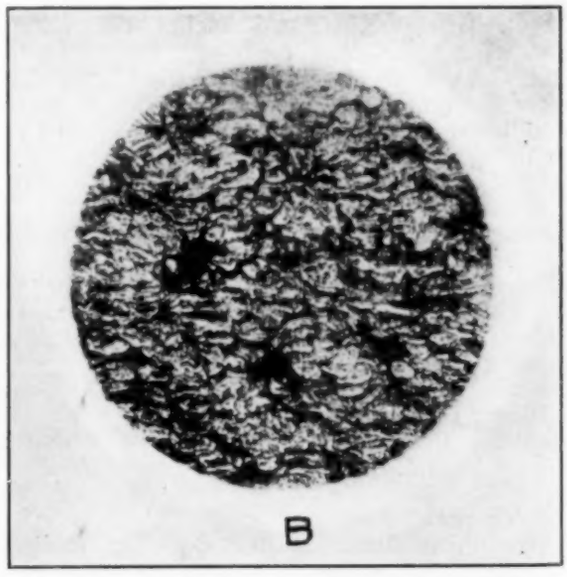

FIG. 2B—GRAY VULCANIZED FIBRE, SP. GR. 1.20

canized fibre photographed across the laminations at a magnification of about 150 diameters, and illustrates very forcibly the homogeneity of the material.

Vulcanized Fibre is not waterproof, but is not injured by immersion in water, either hot or cold, and on re-

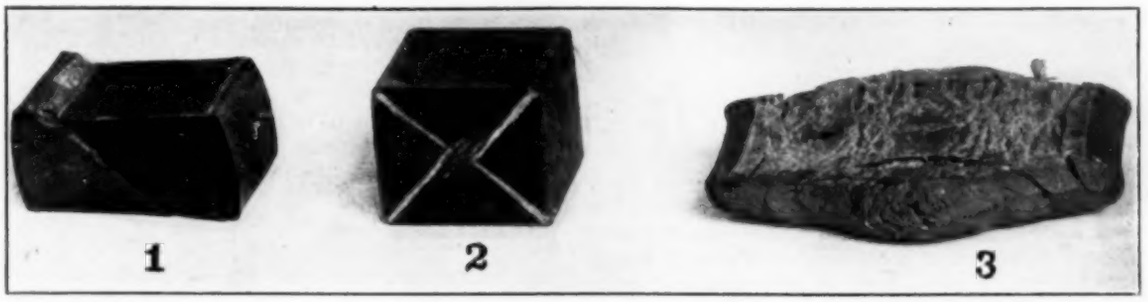

FIG. 4—COMPRESSION TESTS—NO. 1, 38,000 LB. APPLIED ON NATURAL FACES OF 1-IN. FIBRE CUBE—NO. 2, 9000 LB. APPLIED ON EDGE OF 1-IN. FIBRE CUBE—NO. 3, 90,000 LB. APPLIED ON EDGE OF 1-IN. CUBE AS IN NO. 2—NOTE HOMOGENEITY AS SHOWN BY 45-DEG. FRACTURE

drying resumes its original dimensions and properties. Neutral salts are also without any harmful effect, but most mineral acids in time cause disintegration. Organic solvents, such as ether, carbon tetrachloride, etc., and all oils are absolutely without effect on fibre, and are not absorbed in the slightest degree.

The mechanical and physical properties may be varied between fairly wide limits by proper manipulation of the chemical treatment and by varying the quality of the original paper. This fact is little appreciated by the public, and, in fact, only too little appreciated by some of the fibre manufacturers themselves. Consequently a man believing that "fibre is fibre" may purchase a grade absolutely unsuited for his particular needs, and without further investigation conclude that all fibre is worthless to him. To illustrate this point more strongly, we give in Table I the properties for two samples of material both of which sell under the name of Vulcanized Fibre.

FIG. 5—SECTION OF TRACK 4400 FT. IN LENGTH AT McKEE'S ROCKS, ON THE P. & L. E. R. R., WHERE 3000 STEEL TIES WERE INSULATED WITH AMERICAN VULCANIZED FIBER SHIMS THAT HAVE LASTED OVER FIVE YEARS

TABLE I—PROPERTIES OF TWO KINDS OF VULCANIZED FIBRE

	No. 1	No. 2
Thickness	⅛ in.	⅛ in.
Specific gravity	1.100	1.480
24 hours' absorption of water	70%	25%
Chlorine content	0.20%	0.03%
Hardness by scleroscope	25	50
Shearing strength, lbs. per sq. in.	9,000	13,000
Crushing strength, lbs. per sq. in.	33,000	43,000
Tensile strength, lbs. per sq. in.	8,000	13,000
Breakdown voltage	12,500	50,000

At a glance it will be seen that there are great differences in the properties of the two samples, and that the purchaser of fibre must take care how and where he buys in order to be sure that the manufacturer is able to and actually does give him the grade best adapted to his purposes.

Vulcanized Fibre is used in all kinds of electrical insulation; in trunks, roving cans, waste baskets and similar receptacles; and in a great variety of mechanical parts such as gears, valves, washers, bushings, etc. One of its principal applications is in railroad insulation for automatic block signals, shims, etc. Fig. 5 shows an installation of the latter and illustrates the extreme durability of the material. Vulcanized Fibre gears are noiseless and oil-proof and on account of their toughness and elasticity will outwear two or three sets of brass gears. Vulcanized Fibre valves have given continuous service for over three years in feed-water pumps, pumping hot water at 212 deg. Fahr., against 150 lb. pressure, and are far superior to rubber or composition valves for water or any neutral solution.

The tensile strength of Vulcanized Fibre which is three times that of leather, and its high dielectric strength of 200-400 volts per mil, are constantly leading manufacturers as they become more familiar with this interesting material, to adopt it for new uses, and it is hoped that this article may prove of value by suggesting to some puzzled engineer the answer to the frequent query, "What material can I use?"

Research Laboratory,
American Vulcanized Fibre Co.,
Wilmington, Del.

The Titanium Alloy Manufacturing Company has prepared an illustrated booklet entitled "How Titanium Bronze Is Produced." It is profusely illustrated with photographs of the various departments of its works.

The Electrolysis of Copper Sulphate Liquors, Using Carbon Anodes*

BY LAWRENCE ADDICKS

Through the courtesy of Dr. James Douglass, I am permitted to give the results of quite an extended research conducted at Douglas, Ariz., on the possibilities of electrolytic recovery of copper from liquors resulting from sulphate leaching.

Starting with sulphide copper ores or concentrator products therefrom, which was the particular case under consideration, the simplest form of the proposition is to make sulphuric acid from concentrates by the usual roasting procedure, use this for leaching, electrolyze with lead anodes and precipitate upon iron sufficient of the liquor to maintain a reasonable degree of purity in the electrolyte. Such a method is commercial when there is no serious competition by other processes, as where concentrator tailings are very rich in values or where some local handicap to smelting exists, or where there is a profitable market for a surplus of sulphuric acid.

A very different way of attacking the problem was the old Siemens-Halske process, where ferric sulphate was used for the direct consumption of sulphides, the resulting ferrous-cupric sulphate liquor being electrolyzed in a diaphragm cell, obtaining a copper cathode and regenerating the ferric sulphate at the same time. This failed, partly due to the non-existence of a satisfactory diaphragm and partly to the shortcomings of the leaching agent.

Then Tossizza attacked the question by applying the long known action of sulphur dioxide gas as a depolarizer, introducing it directly into the cell, making sulphuric acid in accordance with the inclusive reaction.

$$CuSO_4 + SO_2 + 2H_2O + \text{current} = Cu + 2H_2SO_4$$

and reducing the voltage in proportion to the energy of oxidation at the anode. The direct use of sulphur dioxide as a depolarizer is undesirable for three reasons: (1) The escaping gas makes the atmosphere of the cell room unbearable and the ventilating problem, while perhaps not insurmountable, would be a very serious matter; (2) the gas escapes so readily from a warm liquor in motion that the consumption would be prodigal and there are limits, even though rather liberal ones, upon the quantity available; (3) it is a difficult matter to obtain a sufficient absorption for efficient depolarization, using roaster gas, unless compressors or other complications are resorted to.

The research work finally developed a process based upon the depolarizing value of ferrous sulphate, using a carbon anode, the sedative value of aluminium sulphate (U. S. patent No. 1,138,921) thereby restraining the redissolving of the cathode copper, and the reduction of the ferric sulphate by sulphur dioxide outside of the cell room. It is the purpose of this paper to discuss the various factors involved in this scheme of procedure.

While it is not possible to divorce entirely these different factors, for clearness' sake they will be taken up individually as follows:

1. Circulation and agitation.
2. Anodes and depolarization.
3. Cathodes and corrosion.
4. Sulphur dioxide and reduction of ferric sulphate.
5. Efficiencies.

Circulation and Agitation

In any electrolytic process the constituents of the electrolyte taking part in the oxidation at the anode and the corresponding reduction at the cathode must be continually supplied at the electrodes by some method of circulation at a rate sufficient to satisfy the demands of the current at the density employed. If this is not done the voltage will rise until the next reaction in line occurs, or if the voltage is limited, the current will fall, or flow spasmodically. In our particular case ferrous sulphate must be supplied at the anode fast enough to take up the oxygen released and copper at the cathode in sufficient quantity to prevent the liberation of hydrogen or precipitation of impurities. A relatively low rate of circulation suffices at the cathode if the liquor is reasonably rich in copper sulphate, as demonstrated in ordinary refining with a soluble anode. At the anode, on the other hand, a violent circulation is necessary, and this is best obtained by agitation with compressed air, apart from the relatively low circulation necessary for replenishment.

The reason for this behavior of the anode is doubtless due to the fact that a gas is liberated on a rather rough surface and more or less of a mechanical scouring action is necessary as well as a sufficient concentration of ferrous iron. In ordinary refining work the liquor is circulated at a rate which displaces the contents of a cell in several hours. In this work, at a current density

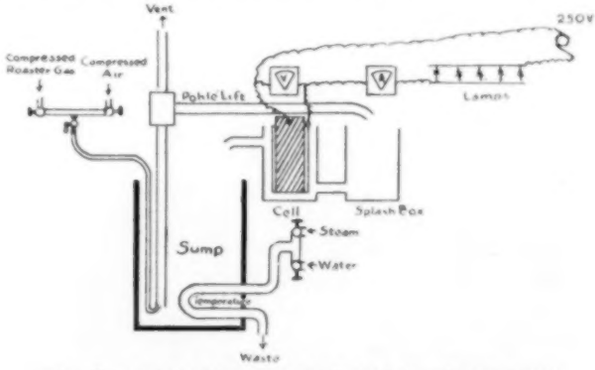

FIG. 1—CELL ARRANGEMENT FOR VOLTAGE TESTS

Carbon anode, 3½ x 4 in. (9 x 10 cm.). Copper cathode, 4 x 4 in. (10 x 10 cm.). Electrodes 1 in. apart (2.5 cm.).

of 4 amp. per square foot (44 per square meter) a relatively low rate of circulation proved adequate, but at 8 amp. per square foot (88 per square meter) the contents of the cell, in small scale experiments, had to be displaced every thirty seconds, and at 16 amp. every twenty seconds, in order to obtain voltages indicating satisfactory depolarization, although these were readily reached by stirring or agitation. Any method of agitation which affords rapid movement of the electrolyte over the face of the anode may be used, but the introduction of compressed air at the bottom of the cell seemed the most practical application.

Fig. 1 is a diagram of the apparatus first used in making these experiments. As the first runs were purely voltage determinations, agitation was dispensed with, a stirring rod being vigorously used at the time a reading was taken. Compressed roaster gas was at first used in the Pohlé lifts, but later air was substituted. After complete voltage records had been obtained for varying current density, composition of electrolyte, temperature, etc., the question of current efficiency was studied, several cells being connected in series and compressed air being introduced through a perforated false bottom in each cell.

Finally large cells were operated, using 600 amp., as shown in Fig. 2, and compressed air was introduced at the bottom of each cell, through a 1½-in. (3.8-cm.) lead pipe, coiled in a spiral and perforated at regular intervals with eighty 3/64-in. (1.2-mm.) holes. Measurements showed that the pressure necessary started

*A paper read at the San Francisco meeting of the American Electrochemical Society Sept. 17, 1915.

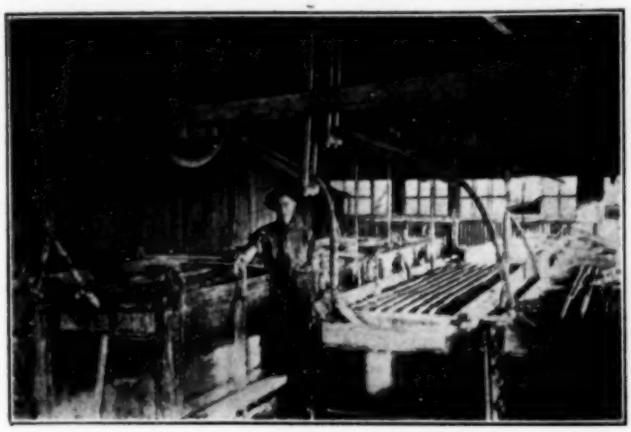

FIG. 2—FULL SIZE CELLS

barely above that of submergence or about 1½ in. (3.8 cm.) of mercury. Then as these holes gradually became choked by crystals or sediments, the pressure rose to about 3 in. (7.6 cm.) of mercury. This would take several hours. Then steam was introduced into the air system for several minutes, which fully cleared it. The quantity of air used was about 500 cu. ft. (14 cu. m.) an hour, and as each cell deposited over a pound (453 gr.) of copper an hour, it will be seen that the power for compressing this air was very small.

The general plan of operation adopted was, therefore, a circulation sufficient to replenish the liquor at a rate which would hold the anode oxidation product—ferric sulphate—at a concentration which would not seriously corrode the cathode, and compressed air agitation sufficient to obtain a minimum voltage by depolarization. An idea of these effects may be obtained from Fig. 3, which shows the voltages in one of the small cells with and without agitation for different current densities and temperatures. It will be noted that rising temperature assists the depolarization while rising current density impedes it.

Anodes and Depolarization

Three commercially possible materials are to-day available for use as insoluble anodes in sulphate liquors:

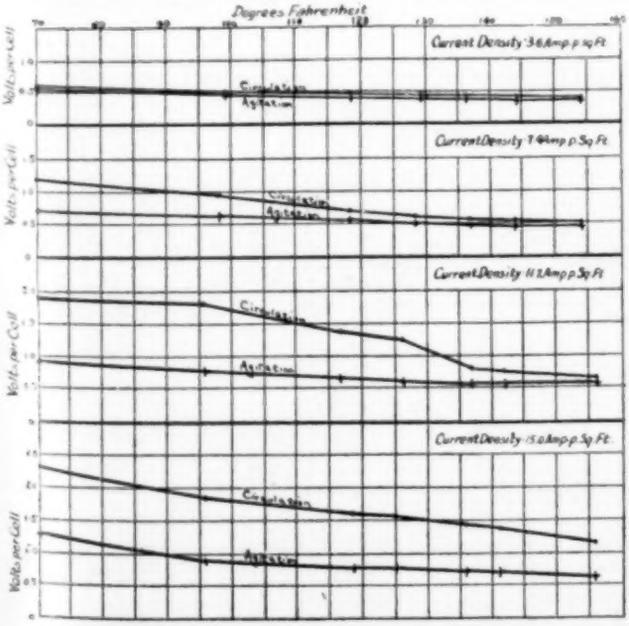
Degrees Fahrenheit
Current Density 3.6 Amp. p. Sq. Ft.
Circulation
Agitation
Current Density 7.9 Amp. p. Sq. Ft.
Current Density 11.2 Amp. p. Sq. Ft.
Current Density 15.0 Amp. p. Sq. Ft.
Volts per Cell

FIG. 3—EFFECT OF AGITATION UPON CELL VOLTAGE

Electrolyte—3.7 per cent Cu, 2.0 per cent Fe, 4.3 per cent Al_2O_3, 4.2 per cent H_2SO_4.

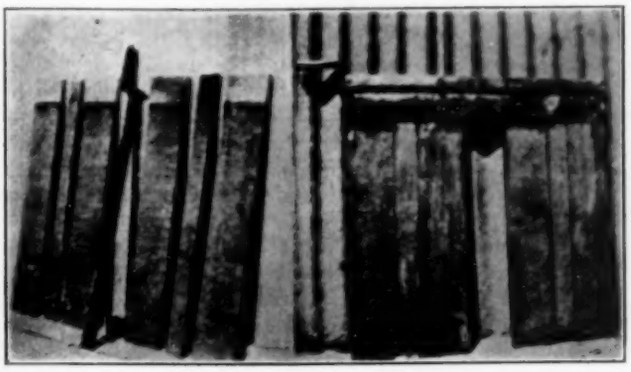

FIG. 4—ANODE PARTS FIG. 5—COMPLETED ANODE

Lead, magnetite and carbon. There are two objections to lead, viz., it does not work at low cell voltages even in the presence of depolarizers, and its life is more or less limited, due to the flaking off of the sulphate and peroxide formed on its surface.

Magnetite is fragile and expensive and it remains to be seen whether it will hold its own in large-scale work. The showing made at Chuquicamata will settle this point.

Carbon has been used for many years as an anode in chloride electrolytes and has given satisfactory service. In many of these cases free chlorine gas has been evolved at the anode, so that the disintegration of the carbon conglomerate in sulphate solutions must be due to the chemical properties of the oxygen formed, rather than to any physical attack. We know that charcoal, for example, has the property of absorbing large volumes of gases and we find that oxygen evolved at a carbon anode will react markedly with depolarizing agents, while oxygen liberated in the same way at a lead anode gives but partial response. It seems likely, therefore, that something akin to ozone is formed at the surface of the carbon anode, and that in the absence of substances susceptible of more ready oxidation, the carbon itself or its more or less carbonized binding material is oxidized and the anode breaks down.

The early work done with electrolytes weak in either sulphur dioxide or ferrous sulphate, showed a very decided softening of the surface of the anode. The later work, after ferrous sulphate was definitely adopted as the depolarizing agent, and a minimum of 1½ per cent ferrous iron kept in contact with the anode by agitation, showed no sign of any deterioration of the anode after several months' use. Nearly all of the work was done with Acheson graphite slabs, but some tests were made with baked carbon slabs and as far as these tests went, no difference was found in the behavior of the two.

The construction of a practical anode out of the ½ x 4 inch (1.25 x 10 cm.) slabs used gave some trouble. After several trials the design shown in Figs. 4 and 5 was developed and gave satisfactory service. The carbon strips were first trued up and the necessary holes drilled. Then they were electroplated with a thin film of copper at the upper end and the copper contact strips attached with copper bolts and nuts. The exposed copper parts were then given a coat of asphaltum paint and a lead apron burned around the entire upper end. This construction prevented the electrolyte from reaching the copper parts and dissolving them either chemically or electrolytically and the voltage drop between bus bar and active anode surface was negligible.

When a piece of carbon and a strip of copper are immersed in an acidulated copper sulphate solution, a voltmeter indicates an open circuit voltage of 0.29 volt,

the carbon being, of course, electro-negative to the copper. This counter e.m.f. has, therefore, to be overcome when using carbon as an anode. The data given in Fig. 3 can be rearranged to show this; this is done in Fig. 6, and brings out clearly the effect of agitation, temperature and current density. No attempt has been made to measure actual polarization voltages or figure the theoretical voltages possible, but the solid lines in this diagram represent the actual voltages obtainable under corresponding working conditions. The liquors used in many of these measurements contained a few hundredths of a per cent of free sulphur dioxide, but it is not believed that this has any bearing on the voltages obtained. All percentages by analysis given in this paper represent grams per 100 c. c., except when measuring the percentage of sulphur dioxide in roaster gas, which is stated by volume.

Next a series of investigations was undertaken on the effect of varying quantities of free acid, iron and alumina in the electrolyte upon the voltage obtainable. In order to keep this paper within reasonable length, but a few representative diagrams will be given from the great number of measurements made and tabulated. Fig. 7 shows the general relation between power and voltage and current efficiency in the electrolysis of cupric sulphate, for convenience in considering the possible recovery per kw.-hr. under various conditions.

Figs. 8 and 9 show the effect of varying the quantity of free sulphuric acid in the electrolyte at a constant temperature of 120 deg. Fahr. (49 deg. C.). As increasing temperature was found of material assistance both in reducing the ohmic resistance of the cell and in rendering efficient depolarization more easily obtainable, a cell temperature of about 115 deg. Fahr. (46 deg. C.) was determined upon when large scale work was taken up. Too high a temperature, on the other hand, increased cathode corrosion, a matter which will be discussed later on. Fig. 10 shows the working voltages obtained with varying acidity in large scale work. It is evident that the acid assists somewhat in the mechanism of depolarization and lowers the resistance of the electrolyte, but that there is no warrant for carrying the high percentage of acid used in regular refining work. The enormous quantity of salts present in the electrolytes used is doubtless the cause of this difference. Most of the work was, therefore, done at an acidity of not less than 4 per cent. Too high an acid content impeded the solution of sulphur dioxide, as will be shown later. The temperature in Fig. 10 was 119 deg. Fahr., the electrolyte contained 4.3 per cent Cu, 3.5 Al_2O_3, 2.4 Fe.

Next the effect of aluminium sulphate was taken up and the results obtained at a temperature of 120 deg. Fahr (49 deg. C.) with varying current densities are shown in Fig. 11, and similar data for a fixed current density with different temperatures in Fig. 12. These two sets of curves have been selected as representative of the general effect alumina has of interfering with depolarization. It was found in regular work that 4 per cent was the maximum which could be carried in the electrolyte without excessive voltage, disproportionate agitation or the production of soapy froth. On the other hand, it is desirable to carry as much as possible on account of its restraining effect upon cathode corrosion. It may be said here that a current density of 13 amp. per square foot (143 per sq. m.) was decided upon as causing about as rapid a production of oxygen at the anode as could be properly handled by the depolarizing agent. Alumina also reduces the absorbing power of liquor for sulphur dioxide.

Next the effect of ferrous sulphate was studied. Fig. 13 shows that in the absence of agitation the voltage decreases in proportion to increasing concentration of ferrous iron but that except at high temperatures even

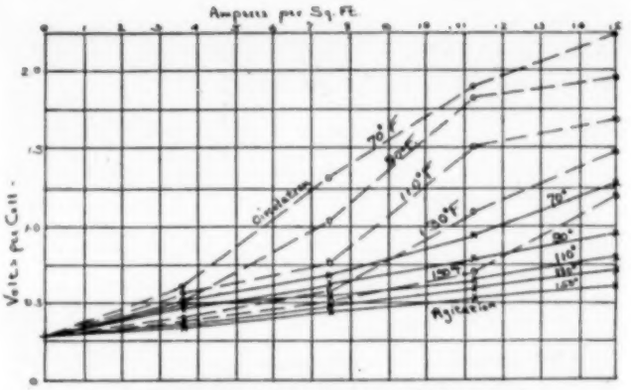

FIG. 6—POLARIZATION DATA FROM FIG. 3

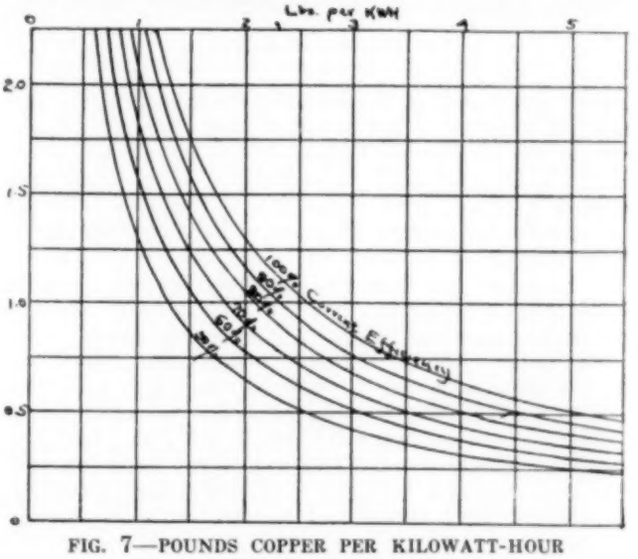

FIG. 7—POUNDS COPPER PER KILOWATT-HOUR

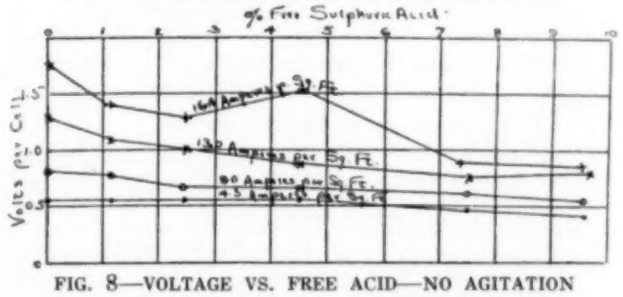

FIG. 8—VOLTAGE VS. FREE ACID—NO AGITATION

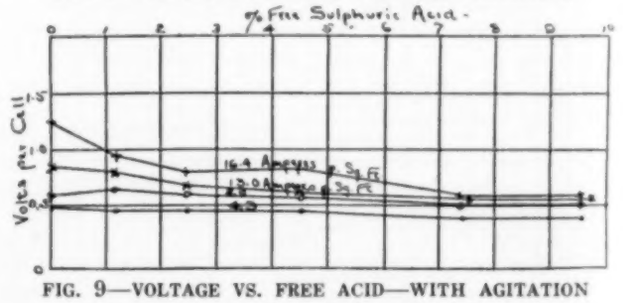

FIG. 9—VOLTAGE VS. FREE ACID—WITH AGITATION

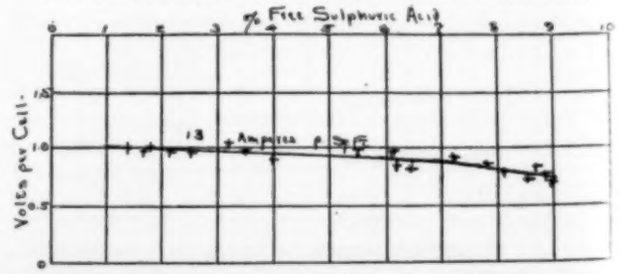

FIG. 10—VOLTAGE VS. FREE ACID—LARGE SCALE WORK 119 DEG. FAHR.

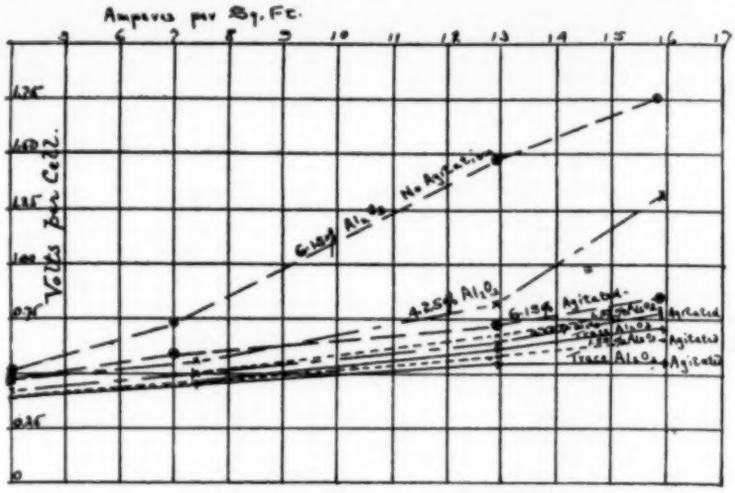

FIG. 11—VOLTAGE VS. ALUMINA

2.5 per cent Cu, 3.3 per cent Fe, 4.3 per cent H_2SO_4, 120 deg. Fahr. (49 deg. C.).

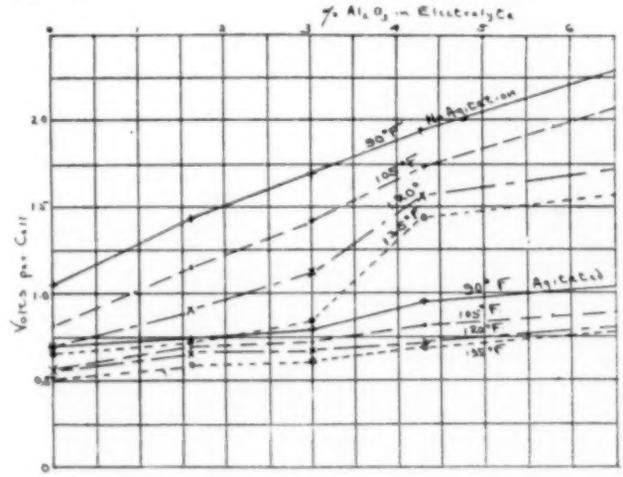

FIG. 12—VOLTAGE VS. ALUMINA

3.1 per cent Cu, 2.4 per cent Fe, 4.0 per cent H_2SO_4, 15.7 amp. per square feet (173 per square meter).

very concentrated solutions give but partial depolarization. On the other hand, with agitation, the voltage drops immediately as iron is introduced, to a minimum

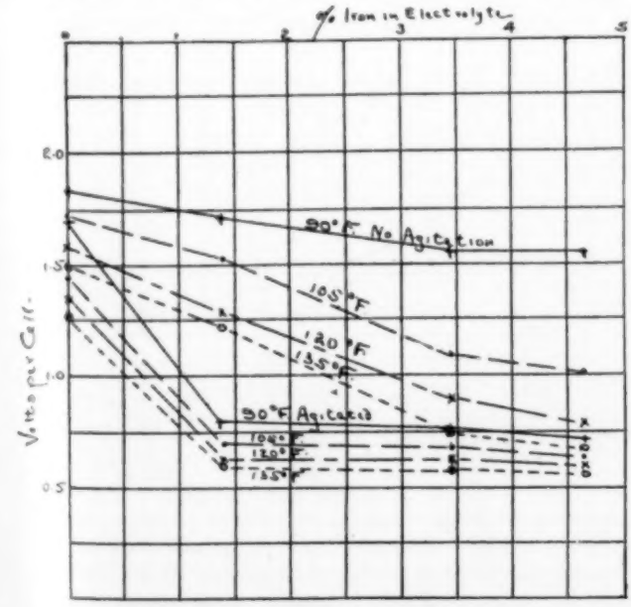

FIG. 13—VOLTAGE VS. IRON

2.6 per cent Cu, 4.4 per cent Al_2O_3, 4.2 per cent H_2SO_4, 12.5 amp. per square foot (137 per square meter).

which is practically unaffected by further additions. No ill effect is produced by very high iron. The reason that agitation slightly lowers the voltage on the zero iron line is probably that the small quantities of sulphur dioxide present in the solutions have a slight depolarizing effect.

The relative values of sulphur dioxide and ferrous sulphate as depolarizing agents are taken up in Fig. 14. A solution showing but the merest trace of iron present by analysis was examined with varying proportions of sulphur dioxide added. Then sufficient ferrous sulphate was added to make the iron content 1.35 per cent. At 90 deg. Fahr. (32 deg. C.) and 13.2 amp. per square foot (145 per square meter), and in the absence of either ferrous iron or sulphur dioxide a voltage of nearly 1.9 is observed. Agitation drops this slightly, to about 1.8 volts. Adding SO_2 up to a content of 0.35 per cent has but little effect in the absence of agitation, but when agitated the cell voltage drops steadily as the strength of SO_2 increases; 0.35 per cent, however, brings the voltage down to but 1.25, and apparently a high content would be necessary to effect anything like the depolarization corresponding to the complete utilization of the anode oxygen. On the other hand, the moment any ferrous sulphate is added, the voltage drops to the value expected. It was, therefore, concluded that the presence in the liquor of the small quantities of sulphur dioxide which it is possible to absorb from relatively weak roaster gases, afforded no gain in depolarizing, while introducing various handicaps in other directions, so that ferrous sulphate was settled upon as the depolarizing agent and a minimum of 1.5 per cent ferrous iron determined upon.

Cathodes and Corrosion

Two problems were encountered at the cathode. The corrosive effect of the ferric sulphate produced at the anode made it difficult to obtain a high current efficiency, and under certain conditions the deposit would be tarnished by a film of copper sulphide.

The first difficulty is expressed by the reaction

$$Cu + Fe_2(SO_4)_3 = CuSO_4 + 2FeSO_4$$

Fig. 15 shows the corrosion rate to be expected in an acid solution of ferric sulphate. It is self-evident that the corrosion may be expressed in terms of weight lost per unit of superficial area of copper exposed to the wash of the liquor. It will be noted that the speed of the reaction is proportioned to the concentration of ferric iron and is greatly accelerated by heat.

The rates of corrosion were measured in a motor-

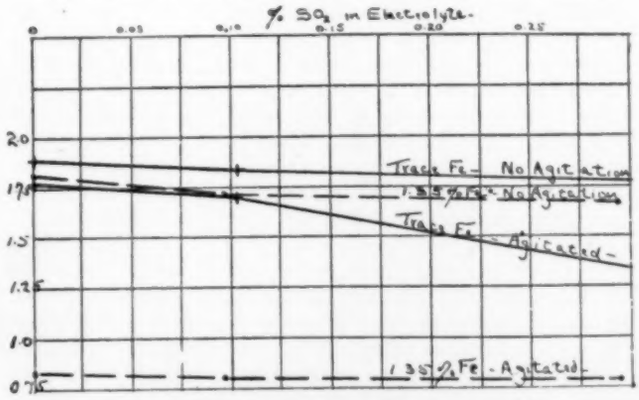

FIG. 14—VOLTAGE VS. SULPHUR DIOXIDE

2.6 per cent Cu, 4.3 per cent Al_2O_3, 4.2 per cent H_2SO_4, 90 deg. Fahr., 13 2 amp. per square foot (145 per square meter).

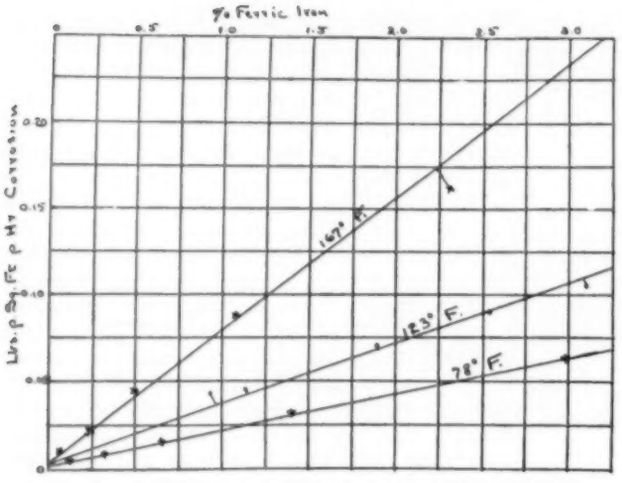

FIG. 15—REDUCTION OF FERRIC SULPHATE BY COPPER
Liquor: 4 per cent H_2SO_4 + × $Fe_2(SO_4)_3$.

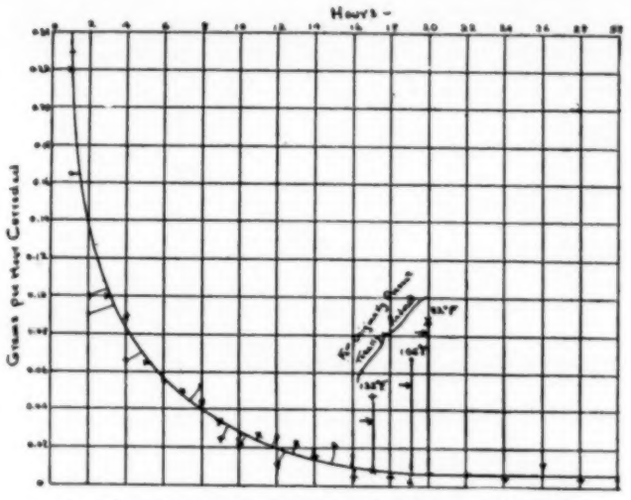

FIG. 16—OXIDATION ERROR OF SHAKING MACHINE
Liquor: 3 per cent Cu, 3 per cent Al_2O_3, 4 per cent H_2SO_4, 2 per cent Fe″, 1.4 per cent Fe‴. Copper strip 2½ sq. in. surface.

driven shaking machine. This same apparatus was also used in the determination of the ferric iron in liquors. When simply a rate of corrosion was desired, the liquor was taken in such quantity that a measurable loss in the weight of the copper strip was obtainable without serious change to the strength of the liquor. When the ferric iron contents of the liquor was to be determined, on the other hand, the quantity of liquor was chosen so that complete exhaustion would not take an unreasonable time. Fig. 16 gives the characteristics of the machine. The oxidation error shown by constant loss in weight of the strip after twenty hours is very small.

The corrosion rates shown in Fig. 15 are very large. Thirteen amperes per square foot (143 per sq. m.) would deposit 0.034 lb. on a square foot (169 gr. per sq. m.) in an hour. From the diagram it appears that about 0.75 per cent ferric iron at 123 deg. Fahr. (51 deg. C.) would corrode as fast as the current deposited. A study was, therefore, made of the possible effects of the other components in the solution with quite remarkable results.

Fig. 17 shows the effect upon corrosion by adding either cupric, ferrous or aluminium sulphate to a liquor carrying 0.2 per cent iron as ferric sulphate and 4 per cent sulphuric acid. The copper and iron have but a slightly depressant effect upon the speed of reaction of the ferric iron upon the copper strip; the alumina, however, has a most marked effect and when the solution is practically saturated with aluminium sulphate the corrosion is almost completely arrested. Fig. 18 shows this same relation for a liquor carrying 3 per cent of both cupric and ferrous sulphates, being within the range of composition of a practical electrolyte. Fig. 19 shows that the amount of free acid present has but very slight effect. It, therefore, was determined to use aluminium sulphate as an antidote to ferric sulphate and it is believed this property of alumina may have wide application. No explanation is offered of the mechanism of this effect. It seems to slow down various reactions; for example, copper appears to cement upon iron with more difficulty. With alumina present, it is more difficult to depolarize, less sulphur dioxide can be absorbed, etc.

The second general difficulty, that of obtaining a bright deposit, was found to be due to the operation of several side reactions depositing either cupric sulphide or cuprous chloride upon the cathode. In the first place the work was done where the climatic conditions caused a tremendous amount of evaporation—some 200 units of water per unit of copper deposited had to be replaced—and the local water was full of salts, mainly chlorides. The electrolyte, therefore, rapidly built up in chlorides

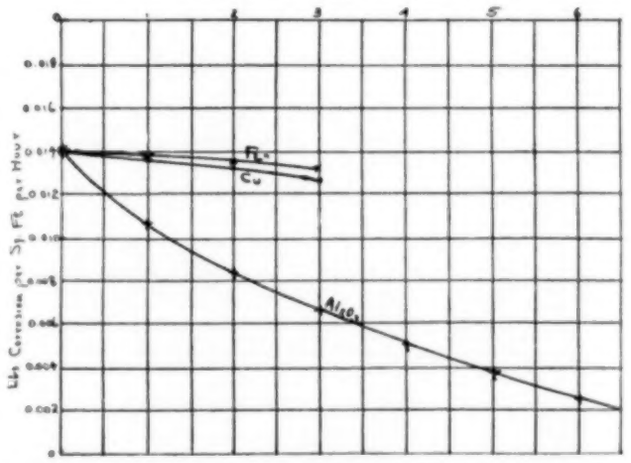

FIG. 17—RELATIVE EFFECTS OF COPPER, IRON AND ALUMINA ON CORROSION
Liquor: 4 per cent H_2SO_4, 0.2 per cent Fe‴, 105 deg. Fahr. (41 deg. C.).

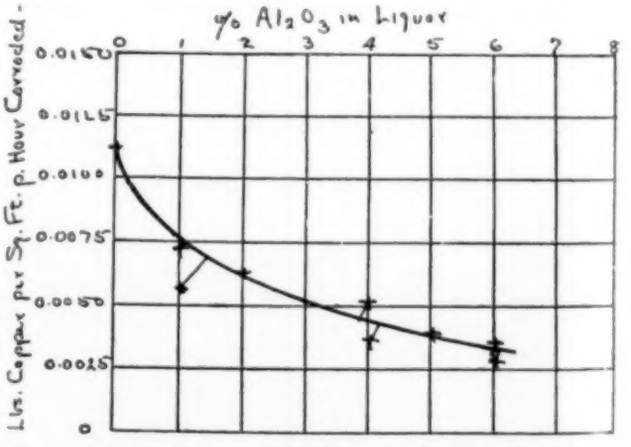

FIG. 18—EFFECT OF ALUMINIUM SULPHATE ON CORROSION
Liquor: 3 per cent Cu, 3 per cent Fe″, 0.2 per cent Fe‴, 4 per cent H_2SO_4, 105 deg. Fahr. (41 deg. C.).

until about 0.1 per cent Cl was found to be present by analysis. This resulted in a precipitation of cuprous chloride on the cathode which, owing to its actinic property, caused a tendency to blacken upon exposure to the light. Chlorine further reacted with the SO_2 when it was present in the liquors to form a cupric sulphide

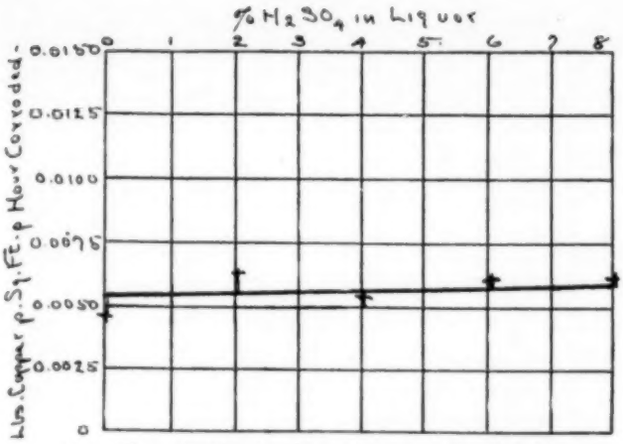

FIG. 19—EFFECT OF FREE ACID ON CORROSION

Liquor: 3 per cent Cu, 3 per cent Fe", 0.2 per cent Fe"', 3 per cent Al_2O_3; 105 deg. Fahr. (41 deg. C.).

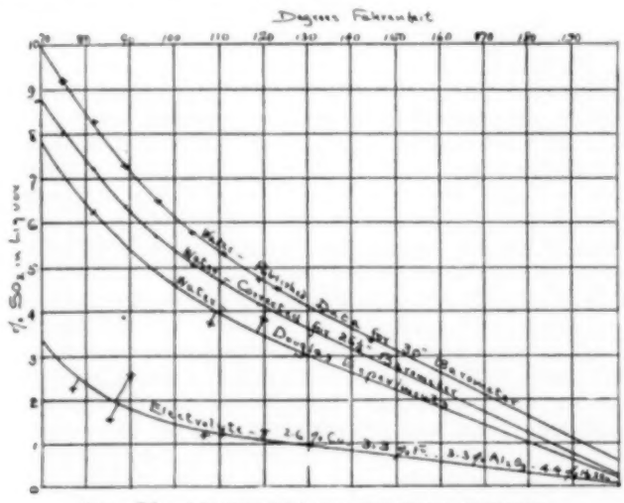

FIG. 20—SOLUBILITY OF SULPHUR DIOXIDE

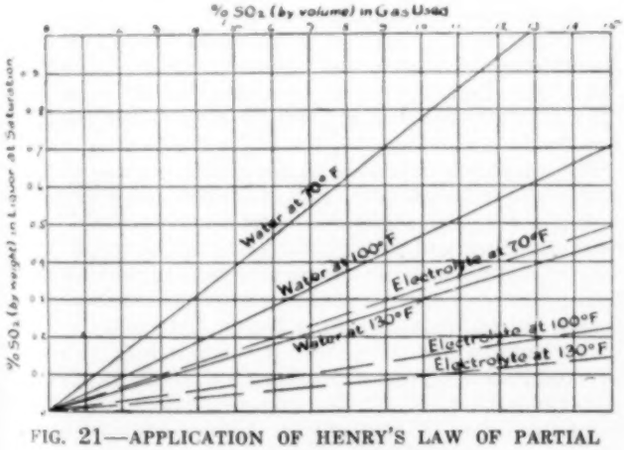
% SO_2 (by volume) in Gas Used
% SO_2 (by weight) in Liquor at Saturation
Water at 70°F
Water at 100°F
Water at 130°F
Electrolyte at 70°F
Electrolyte at 100°F
Electrolyte at 130°F

FIG. 21—APPLICATION OF HENRY'S LAW OF PARTIAL PRESSURES TO FIG. 20

film on copper. Finally unless the reduction of ferric sulphate by sulphur dioxide was carried out under proper conditions, some unknown practical products of reduction were formed which appeared to reduce to cupric sulphide at the cathode.

A brilliant deposit can easily be obtained where the liquor in the cells is free from chlorides or sulphur dioxide and any previous reduction of ferric sulphate has been properly carried out.

Sulphur Dioxide and Reduction of Ferric Sulphate

In Fig. 20 is given some data regarding the solubility of sulphur dioxide. In common with other gases its

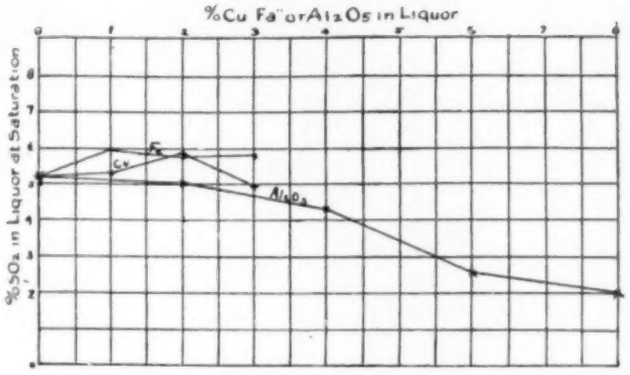

FIG. 22—EFFECT OF VARIOUS SULPHATES UPON SOLUBILITY OF SO_2

Liquor: 4 per cent H_2SO_4, 0.2 per cent Fe"; 70 deg. Fahr. (21 deg. C.).

solubility varies directly with the pressure and diminishes with increase of temperature until practically none remains in solution at the boiling point of the solvent. The curves in Fig. 20 are all for pure SO_2 gas at atmospheric pressure. The top curve is plotted from data in the published handbooks for the solubility of 100 per cent SO_2 in water at various temperatures at sea level and the next one corrects these data to the 26.25 in. (668 mm.) barometer under which the local experiments were made. The next lower curve shows the results obtained by simply bubbling gas through water until no further increase in dissolved SO_2 could be found by titration with iodine. The bottom curve gives the results of similar work using electrolyte as the solvent and a great decrease in the amount of SO_2 which can be absorbed will be noted. Of course, if the gas used runs less than 100 per cent SO_2, a corresponding diminution of the absorption value will be noted and Fig. 21 is a rearrangement of some of the data in Fig. 20, which shows just what can be expected with various strengths of roaster gas.

Figs. 22 and 23 are examples from a complete set of tests made, showing the effect of copper, iron and aluminium sulphates and free acid upon the solvent power of the liquor. It will be noted that the first two have but little effect, while the last two diminish markedly the amount of gas which can be dissolved. Supposedly 100 per cent gas was used in these tests. Fig. 24 shows the actual absorption obtained in practice, using a roaster gas in a tower some 6 ft. (1.8 m.) in diameter and 25 ft. (7.5 m.) high, packed with coke. In general it will be seen that we cannot hope to get more than a maximum of 0.2 per cent free SO_2 by analysis in electrolyte under operating conditions, unless compression of the roaster gas is resorted to. The furnace used was an ordinary six-hearth, 18-ft. (5.4 m.) MacDougall, arranged for metallurgical work, sending gases to waste so that 6 per cent SO_2 by volume was the maximum richness of gas obtainable.

We have three available reducing agents for ferric sulphate—sulphur dioxide, cement copper and the calcines leached as a source of copper.

For complete reduction, about 0.5 unit of sulphur as SO_2 is required for each unit of copper deposited, the iron sulphate acting as a carrier of oxygen from the anode to the SO_2 tower. As copper-bearing sulphide minerals generally carry about 2 units of sulphur per unit of copper, we have a margin of 75 per cent of the sulphur contents to cover losses in calcines, escaping tower gases and free SO_2 absorbed but later blown out of the liquors. The 0.5 unit utilized will add approximately 1.5 units free sulphuric acid to the system, which represents the amount of acid which would have to be

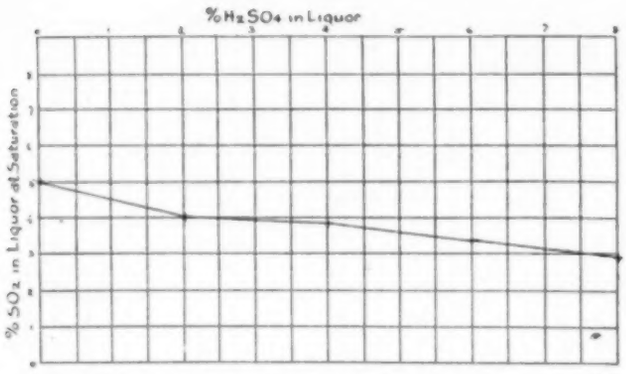

FIG. 23—EFFECT OF FREE ACID UPON SOLUBILITY OF SO_2

Liquor: 0.2 per cent Fe″, 3 per cent Cu, 3 per cent Fe‴, 3 per cent Al_2O_3, 62 deg. Fahr. (17 deg. C.).

run away in purifying the electrolyte were SO_2 the sole source of reduction utilized.

There are several difficulties involved in the use of sulphur dioxide as a reducing agent, aside from the impossibility of obtaining a concentration stronger than 0.15 to 0.20 per cent in the liquors. When an acidified solution of ferrous sulphate is made up, it is a very pale green in color. Copper sulphate added to this at once masks this green entirely and the liquor appears a true blue. When this liquor is oxidized by anodic oxygen or by hydrogen peroxide, for example, the ferric sulphate formed turns it a bluish green. Now when SO_2 is bubbled through, it would be expected that the original blue would be restored, but unless the liquor is quite warm this is not the case, and if the liquor is hot the amount of gas absorbed is so small that but a small amount of reduction will exhaust its power. In a cool liquor the SO_2 turns the liquor a brilliant grass green, and it requires either heating to about 160 deg. Fahr. (71 deg. C.) or a period of rest of some sixteen hours to restore the blue color indicative of complete reduction. Neither of these methods are commercially practicable and the way of escape appears to be to use warm liquors, circulating them through the cells at such a rate that but about 0.1 per cent Fe is oxidized in transit, which small quantity a very small amount of free SO_2 seems capable of quickly reducing.

The next step is to use a certain proportion of cement copper as a reducing agent after the liquor leaves the tower. This not only readily reduces any traces of ferric iron or partial reduction compounds remaining, but precipitates any chlorides as cuprous chloride as

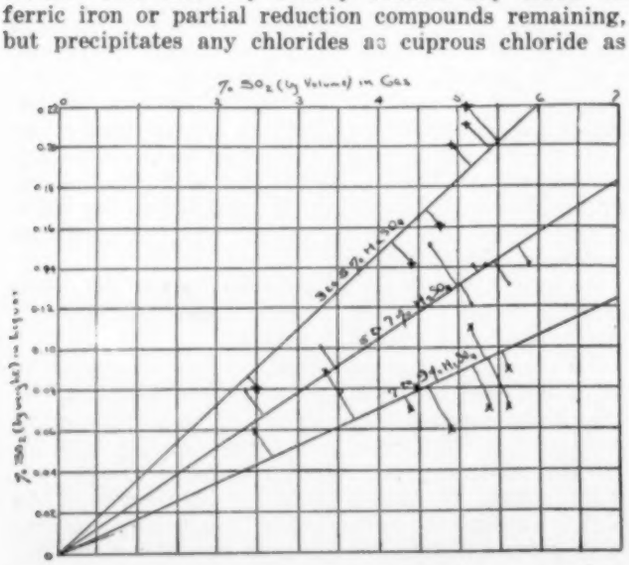

FIG. 24—SO_2 ABSORBED FROM ROASTER GAS IN PRACTICE

Liquor about 3 per cent Cu, 2.5 per cent Fe″, 0.3 per cent Fe‴, 3.7 per cent Al_2O_3, 85 deg. Fahr. (29 deg. C.).

well. Whatever iron, alumina or other impurities are dissolved from the calcines in leaching will have to be removed by systematic withdrawals of electrolyte which can be cemented upon iron. Perhaps 15 per cent of the copper leached will pass through this channel, and the method proposed forms an easy way of converting it to cathode copper.

The calcines to be leached are a fairly effective reducing agent for ferric sulphate, and at least half of the ferric iron contents of a liquor are reduced when passed through the leaching plant.

Efficiencies

We are interested in four efficiencies:

(1) *Current efficiency of cathodes.*
(2) *Quality of cathode.*
(3) *Efficiency of oxidation at anode.*
(4) *Sulphur efficiency.*

CURRENT EFFICIENCY AT CATHODE

About fifty separate runs were made in the cells shown in Fig. 2, during which some 4 tons of cathodes were deposited. The anodes shown in Fig. 5 were held rigidly in place on the cells, eight anodes and seven pairs of cathodes being used in each cell. In most of the work the liquor was circulated through four cells in series. The cathodes shown in Fig. 25 were freely suspended from their supporting bars by hooks made from insulated wire, but spacing blocks were so arranged that when the cathodes rocked under the influence of the compressed air agitation employed, they could not touch the anodes and cause short circuits. As mechanical short circuits were supposedly impossible, and as the agitation resulted in a beautifully smooth deposit without any tendency to form trees, we will assume that any deficiency from 100 per cent efficiency at the cathode was due to redissolving of the copper by ferric sulphate formed at the anode.

We have six factors influencing the rate of corrosion at the cathode; the concentration of ferric sulphate in the electrolyte, the temperature of the electrolyte, the concentration of aluminum sulphate in the electrolyte, the efficiency of contact with the cathode due to agitation, the surface exposed to corrosion and the offsetting effect of the rate of deposit, or, in other words, current density.

The influence of the first of these factors, the concentration of ferric sulphate, under operating conditions, is shown in Fig. 27, where the average of the ferric sulphate entering and leaving the cells in the large scale runs is plotted against the current efficiency obtained. The existence of other variables scatters the points more or less, but the relationship is clearly indicated.

The temperature of the electrolyte was held at about 120 deg. Fahr. (40 deg. C.) entering the cells in most of the large scale runs. In the presence of aluminum sulphate the effect of temperature upon corrosion is not very marked.

The aluminium sulphate was consistently held above 3 per cent and in general the protective relationship established in the small tests was verified.

The rate of agitation employed was determined entirely by the voltmeter readings. The higher the alumina the greater the agitation called for and a limit around 4 per cent Al_2O_3 was reached where the cells foamed badly.

The surface exposed to corrosion enters in rather an unexpected way. As long as the current efficiency is 65 per cent or over, the corrosion seems quite uniform and the cathode remains relatively smooth. Below this efficiency, however, the corrosion cuts grooves or furrows in the cathodes. These furrows present increased

surface to corrosion and an unstable condition ensues which causes the efficiency to fall day by day until a very low value is reached. The difference in appearance between cathodes which have been operating above and below this critical value is shown in Figs. 25 and 26.

The current density in the large scale runs was held at 13 amp. per square foot (143 per square meter) because it was found difficult to obtain thorough depolarization at higher rates.

QUALITY OF CATHODE

Physically, most beautiful cathodes were made when the rate of corrosion was properly controlled. This was, of course, due to the burnishing effect of the agitation in the cells. Chemically, three possibilities have to be considered—fouling by cuprous chloride, contamination by copper sulphide and plating out of arsenic, etc.

Cuprous chloride is purely a local problem where the water supply or the calcines carry chlorides and the use of cement copper appears to be an adequate remedy. Some cathodes made without the use of cement, analyzed 2.9 per cent Cl, while others made where cement was used showed 0.4 per cent Cl, indicating that a more thorough use of the cement would eliminate the cuprous chloride without difficulty. This same problem is being handled at Chuquicamata by precipitating upon shot copper.

The proper reduction of ferric sulphate by sulphur dioxide will not leave partial compounds which blacken the cathodes. While some of the earlier copper showed the presence of sulphur, the later runs gave out 0.002 to 0.003 per cent.

Small scale experiments, using an electrolyte to which 1 per cent arsenic as As_2O_3 had been added, yielded cathodes running but 0.0011 per cent As.

ANODE EFFICIENCY

The anode efficiency was ascertained for twenty-seven of the large-scale runs, as follows:

The theoretical oxidation of ferrous sulphate was calculated from the cell—ampere—hours for each run. The gain in ferric sulphate was then figured from the quantity of liquor circulated and the shaking machine determinations on the entering and leaving liquors. To this was added the quantity of ferric iron reduced at the cathode as shown by the current efficiency, the sum being the iron actually oxidized electrolytically at the anode and chemically by the air used in agitation. The results ran in general from 90 to 115 per cent. Some runs, to determine the amount of oxidation due to the air, indicated perhaps 15 per cent, so that the depolarization was apparently perfect.

SULPHUR EFFICIENCY

We have available, in general, 2 units of sulphur per unit of copper. We lose perhaps 10 per cent in the calcines and some, let us say another 10 per cent, must be lost in the exhausted tower gases. We have an anode efficiency of oxidation of say 110 per cent, including that due to the agitation. This will call for 0.55 unit sulphur per unit of copper, in the form of SO_2, to reduce the equivalent ferric sulphate. We have, therefore:

Lost in calcines	0.20 unit
Lost in tower gases	0.20 unit
Used in reduction	0.55 unit
Total available	0.95 unit 2.00 unit
Possible loss in liquor	1.05 unit S per unit Cu.

If we assume 0.15 per cent free SO_2 in liquor leaving the tower, this 1.05 units will supply 700 units of liquor. We must, therefore, remove 1 unit of copper by deposition from 700 units, or less, of liquor. This corresponds

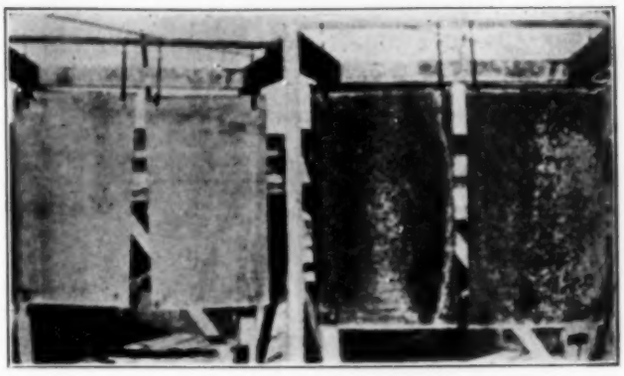

FIG. 25—SMOOTH CATHODES FIG. 26—FURROWED CATHODES

to an oxidation of 1.77 units of iron, or 0.25 per cent increase in ferric iron in passing through the cells. This comes within the danger limit shown by Fig. 27. If we wish to run at lower ferric iron increase we must recover some of the free excess SO_2 in the liquor and

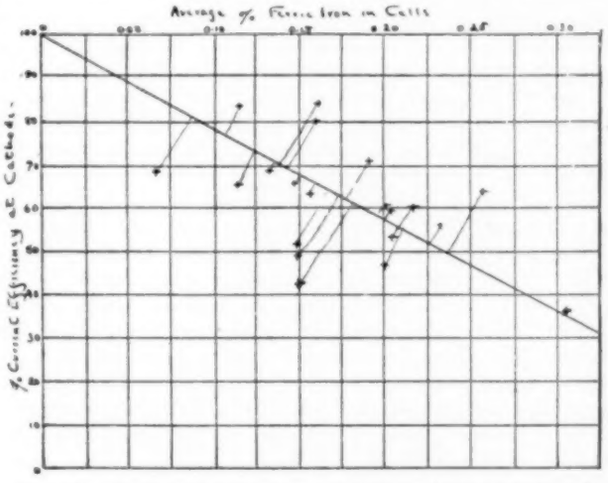

FIG. 27—EFFECT OF FERRIC SULPHATE UPON CURRENT EFFICIENCY IN PRACTICE

Liquor about 5 per cent H_2SO_4, 3 per cent Cu, 2.5 per cent Fe", 3.7 per cent Al_2O_3, 118 deg. Fahr. (48 deg. C.).

use it again in a secondary tower, or figure on less than 0.15 per cent in the liquor leaving the tower.

CONCLUSIONS

Carbon anodes will stand up in sulphate liquors if they are properly depolarized.

Aluminium sulphate can be used as a substitute for a diaphragm.

2.25 lb. (1.019 kg.) of copper per kilowatt-hour can be recovered under proper operating conditions.

Great quantities of various sulphates present as impurities do not foul the cathodes.

Three or possibly 3.25 units of acid are made per unit of copper, of which 1.5 to 1.75 units are new acid from the tower gases.

No mechanical difficulties are experienced in the tower, but a thorough study remains to be made of the chemistry of reduction of ferric sulphate by sulphur dioxide in order to utilize the roaster gas to best advantage.

The New Jersey iron mines in Morris County are reported to be very active, foremost among these being the Empire Steel & Iron Co. at Mount Hope and the Thomas Iron Co. at Richard Mine. The former is shipping about 17,000 tons of ore per month and the latter 6000 tons.

Recent Advances in the Manufacture of Cyanogen Compounds*

BY J. E. CLENNELL

Fixation of Atmospheric Nitrogen

Much activity has been shown of late in the study of methods for the fixation of atmospheric nitrogen, and a number of products are now made on a large scale both for direct use and as a basis for the production of other nitrogenous substances. The most remarkable development has been in the manufacture of calcium cyanamide, $CaCN_2$. Impure commercial products consisting mainly of this substance are now extensively used as fertilizers under the names of "lime nitrogen" and "nitroline." Alkali cyanides and other cyanogen compounds are obtained by further treatment of cyanamides in a variety of ways. Other processes are used to transform cyanamide into ammonia, ammonium salts and other nitrogenous compounds of commercial value.

The earlier attempts at the fixation of atmospheric nitrogen were mostly based on the reactions taking place between barium oxide, carbon and nitrogen at high temperatures. An important investigation of this process has been published by Thomas Ewan and Thomas Napier,[1] who summarize the chief data obtained by previous investigators in this field. The formation of cyanides from a mixture of BaO, C and N requires a minimum temperature of 1200 deg. C., but proceeds best at 1400 deg. C., when 40 per cent of the Ba may be cyanized. Hempel (1890) showed that the percentage of Ba cyanized may be increased by pressure. Readman (1894) applied the electric furnace for this process, which has been carried out on a large scale by the Scottish Cyanide Company. Frank and Caro showed (1898) that a large part of the nitrogen is fixed in the form of barium cyanamide, $BaCN_2$. Caro also found (1907), that the addition of alkali and alkaline earth fluorides accelerates the reaction, and enables it to proceed at temperatures of 900 deg. to 1100 deg. C. Snodgrass (1907) showed that potassium carbonate has a similar action.

Ewan and Napier (1909) studied the action of catalysts to obtain the reaction at lower temperatures. In their first experiments, mixtures of barium carbonate and charcoal were placed in an iron boat in a porcelain tube, and heated in a current of dry nitrogen. The products finally obtained were barium cyanide $Ba(CN)_2$, barium cyanamide $BaCN_2$, carbon monoxide CO, and unaltered $BaCO_3$, C and N. The following reactions are supposed to occur:

$$BaO + 2C + N_2 \rightleftarrows BaCN_2 + CO$$
$$BaO + 3C + N_2 \rightleftarrows Ba(CN)_2 + CO$$

They summarize their results as follows:

1. Absorption of nitrogen begins at 900 deg. to 930 deg. C.

2. The amount absorbed increases rapidly from 1 per cent Ba combined at 930 deg. to 40 per cent at 1000 deg., in tests made under the conditions that four molecules of N act on one molecule of $BaCO_3$ for a period of two hours.

3. The greater part of the nitrogen is fixed as cyanide $Ba(CN)_2$ and not as cyanamide. When calcium is used in place of barium, the nitrogen is fixed almost exclusively as cyanamide, $CaCN_2$.

4. At 960 deg. about 2½ per cent of the nitrogen is fixed; at 1000 deg. about 10 per cent.

5. Addition of K_2CO_3 seems to improve the result, but the difference obtained falls within the limits of error in estimating temperatures.

6. No cyanide is produced until about 30 per cent of the $BaCO_3$ is converted into BaO, and until the percentage of CO has fallen to 30.

It is commonly supposed that barium carbide (BaC_2) is formed as an intermediate product, but Ewan and Napier find no evidence of this. From theoretical considerations BaC_2 could not be formed at all in presence of mixtures of CO and N from which N is freely absorbed by BaO and C. It is probable, however, that when calcium is used instead of barium the reaction:

$$CaC_2 + CO \rightleftarrows CaO + 3C$$

is a necessary intermediary.

Cyanid Gesellschaft[2] reports that nitrogen has no action on a mixture of CaO and C at 1100 deg., and that the reaction $CaO + 2C + N_2 = CaCN_2 + CO$ takes place best at 2000 deg. At this temperature nearly all the nitrogen is absorbed.

K. Kaiser[3] observes that if barium oxide or carbonate, intimately mixed with carbon, be heated to 900 deg. to 1400 deg. C. and allowed to cool in a dry atmosphere of nitrogen under pressure, as much as 90 to 95 per cent of the theoretical amount of nitrogen combines with the barium.

A French patent[4] of 1913 describes a method of carrying out the reaction between barium carbonate, carbon and nitrogen in an electric furnace. Tar is used as binding material for the ingredients; these are molded into balls and part of the bar recovered by distillation. The residue is then heated to 1600 deg. C. in the electric furnace and acted on by "producer gas" or other gas containing nitrogen, to form barium cyanide. The electrodes consist of two rings of carbon placed at the ends of the middle reaction zone of an inclined cylindrical furnace; the fused mass serves to conduct the current. Barium oxide may be regenerated by decomposing the barium cyanide by means of steam:

$$Ba(CN)_2 + 3H_2O = BaO + 2NH_3 + 2CO$$

When calcium is used instead of barium as the vehicle for the fixation of nitrogen, it was found by Barzano and Zanardo[5] that the yield of calcium cyanamide is increased by mixing calcium carbide with sufficient calcium cyanamide from a previous operation to form a friable mass, before subjecting it to the action of nitrogen.

The manufacture of cyanamide by the process of Frank and Caro is carried out on a large scale at the works of the American Cyanamide Company, Niagara Falls, Ontario.[6] Nitrogen is obtained by passing air over heated copper. The copper oxide thus formed is again reduced by the action of natural gas, so that it may be used repeatedly. Operations began in January, 1910, with a 10,000-ton plant, which has since been largely extended.

Cyanides and cyanamides of the alkali metals may be produced without the preliminary formation of a calcium or barium compound. E. A. Ashcroft[7] proposes to do this by using an alloy of the alkali metal with some heavy metal such as lead, and first fusing this with a portion of the product sought (e. g., NaCN or Na_2CN_2) at about 600 deg. C., to separate the alkali from the heavy metal. The resulting melt, freed from the heavy metal, is now caused to react with cyanogen or a substance yielding cyanogen, with or without electrolysis of the melt.

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*The second part of a paper entitled "Recent Advances in the Chemistry of the Cyanogen Compounds," to be presented at the New York City meeting (February, 1916) of the American Institute of Mining Engineers. The first part of the paper deals with advances in the chemistry of ore treatment by cyanide.

[1]Journal Soc. Chem. Ind., vol. 32, p. 467 (May 15, 1913).

[2]English Patent 16,298, 1902.

[3]French Patents 454,237 and 454,238, Feb. 11, 1913.

[4]F. Gros, P. Goissedet, F. Bouchardy and M. Fossier. French Patent 460,684, July 23, 1913.

[5]French Patent 456,826.

[6]Metall. & Chem. Eng'ing, vol. 12, p. 265 and vol. 13, p. 213.

[7]English Patent 1002, Jan. 12, 1912.

Conversion of Cyanamides Into Cyanides, Etc.

We must now mention some of the recently proposed methods for converting calcium cyanamide into cyanides or other nitrogenous substances of commercial value. These may be roughly classified as fusion methods and wet methods.

Among the former, probably the best known is that of Erlwein and Frank[8] by which the crude calcium cyanamide is converted into a product containing the equivalent of 25 to 30 per cent KCN, by fusing with carbon and common salt. Careful regulation of the temperature appears to be necessary. I have found that the process is not easily imitated in laboratory experiments. The product has been placed on the market under the name of "surrogat." For extraction of precious metals, it appears to be as effective, per unit of cyanogen contained, as ordinary sodium cyanide. It requires, however, to be digested with water and the insoluble carbonaceous residue filtered off before use.

J. C. Clancy[9] proposes to heat calcium cyanamide with its own weight of a mixture of equal parts of sodium sulphide and chloride in presence of carbonaceous matter.

E. E. Naef[10] treats crude calcium cyanamide at a temperature of 300 to 500 deg. C. with sulphur or a substance yielding sulphur:

$$2CaCN_2 + S = CaS + Ca(CN)_2 + N_2$$

The product is then stirred with water and filtered from the residue of CaS + C. The filtrate is boiled gently with zinc dust, and the zinc cyanide formed converted into alkali cyanide by known methods.

Calcium cyanamide may be used as a source of ammonia by acting on it with steam under pressure at a temperature of 170 deg. C., using an agitator to prevent formation of lumps. C. Manuelli[11] observes that under favorable conditions nearly theoretical yields of ammonia can be obtained at a cost of about 1.7 cents per pound of nitrogen utilized. Another method (E. E. Naef)[12] is to pass a current of dry hydrogen, either alone or mixed with CO_2, CO or N, at ordinary or higher pressure, over a heated mass of calcium cyanamide.

The wet methods are based on the fact that cyanamide compounds, such as $CaCN_2$, are transformed by water into the sparingly soluble crystallizable salt dicyandiamide $(CN{\cdot}NH_2)_2$. At a temperature of 13 to 14 deg. C. about 90 per cent of the nitrogen of calcium cyanamide may be dissolved in twenty-five times its weight of water, in eight hours, the extraction proceeding rapidly at first but very slowly later (C. Manuelli)[11]. Various salts of dicyandiamide may be prepared by digesting the substance in presence of acids with the oxides of the metals whose salts are required. The polymerization of cyanamide in aqueous solution is promoted by addition of fixed alkalis or ammonia. According to Grube and Krüger,[13] the reaction appears to be due to the union of undissociated cyanamide $(CN{\cdot}NH_2)$ with cyanamide ions $(CN{\cdot}NH)'$, to form monobasic dicyandiamide ions $H{\cdot}(CNNH)'_2$, presumably in the following stages:

(*a*) Formation of cyanamide by hydrolysis of calcium cyanamide:

$$CaCN_2 + 2H_2O = Ca(OH)_2 + CN{\cdot}NH_2$$

(*b*) Dissociation of a part of the cyanamide:

$$CN{\cdot}NH_2 = H' + (NC{\cdot}NH)'$$

(*c*) Combination of dissociated with undissociated cyanamide:

$$(CN{\cdot}NH)' + CN{\cdot}NH_2 = H(CN{\cdot}NH)'_2$$

(*d*) Formation of dicyandiamide:

$$H(CN{\cdot}NH')_2 + H' = (CN{\cdot}NH_2)_2$$

It is found that at a given concentration of total cyanamide, polymerization proceeds most rapidly when the concentrations of cyanamide and of dissociated cyanamide ions are equal.

For the preparation of dicyandiamide from commercial calcium cyanamide, the addition of a foreign base is unnecessary; the conversion may be brought about by precipitating the lime at intervals so as to maintain approximately equal concentrations of $CN{\cdot}NH_2$ and $(CNNH)'$.

Alkali salts of dicyandiamide are produced by heating the substance with caustic alkalis in presence of an absorbent of water:[14]

$$4NaOH + (CNNH_2)_2 = (CN{\cdot}NNa_2)_2 + 4H_2O$$

If the water is not absorbed, part of it reacts with the melt thus:

$$Na_2CN_2 + 3H_2O = Na_2CO_3 + 2NH_3$$

The absorbents used are alkali or alkaline earth metals or their oxides, amides, nitrides, carbides or alloys.

Dicyandiamide is converted into cyanide by fusing with alkaline carbonates and carbon

$$(CN{\cdot}NH_2)_2 + Na_2CO_3 + 2C = 2NaCN + NH_3 + N + H + 3CO$$

or it may be converted into a variety of nitrogenous products suitable for manures, explosives, etc.

The conversion of cyanamide into dicyandiamide may also be brought about by heating its solution with a catalytic agent. H. Immendorf and H. Kappen[15] propose to carry out this process by means of ferric oxide on hydrate, manganous or manganic oxides or their hydrates, stannic acid, chromic oxide or hydrate, hydrated silicic acid or similar substances. The products obtained are ammonia, urea and dicyandiamide. During the process the catalyst absorbs the bases liberated and loses its efficiency. This may be restored by treatment with acid or with water. Commercial calcium cyanamide contains calcium chloride, which hinders the separation of urea and dicyandiamide. This difficulty may be avoided by converting the calcium chloride into sulphate or carbonate, which may be separated by reason of their insolubility in alcohol.

H. Kappen[16] obtains thiourea by treating dilute aqueous solutions of cyanamide with hydrogen sulphide at high temperatures, in closed vessels under pressure. The addition of acid and alkaline reagents and of soluble compounds of arsenic, antimony or tin increases the efficiency of the process.

Production of Cyanogen Compounds from Nitrogenous Gases by Catalysis and Otherwise

Another method for the manufacture of cyanides and related compounds, which has been largely developed of late years, consists in the contamination, under suitable conditions, of volatile carbon and nitrogen compounds. Usually this takes place at a high temperature under the influence of a "catalyst," *i.e.*, of some substance which does not undergo any permanent chemical change in the process.

It has long been known that hydrocyanic acid or ammonium cyanide could be produced by passing mixtures of carboniferous and nitrogenous gases over heated platinized pumice, as for example in Wolterech's process:[17]

$$CO + NH_3 = HCN + H_2O$$

C. Beindl[18] proposes to form hydrocyanic acid and

[8]U. S. Patent 708,333.
[9]U. S. Patent 1,112,893, Oct. 6, 1914. Assigned to Portland Mining Co.
[10]English Patent 14,607, June 22, 1912.
[11]Annali Chim Appl. 1914, 1, p. 388 and 412.
[12]English Patent 14,412, June 20, 1912.
[13]Zeit. f. Phys. Chem., vol. 86, p. 65. 1913.
[14]Chem. Fabr. von Heyden, A. G. German Patent 267,595. Feb. 2, 1913.
[15]German Patent 256,524, Dec. 25, 1910.
[16]German Patent 260,061, Nov. 1, 1911.
[17]English Patent 19,804, 1902.
[18]German Patent 254,068, Feb. 15, 1912.

cyanogen compounds by catalytic combination of gaseous and volatile carbon compounds with gaseous and volatile nitrogen compounds, by the use of a contact material consisting of a metallic oxide or a mixture of metallic oxides. The gaseous mixture should contain not more than 7 volumes of the carbon compound to 1 volume of the nitrogen compound. It is claimed that oxides of metals of the iron group have the property of inducing the rapid formation of hydrocyanic acid at relatively low temperatures, from dry mixtures of these gases.

It has been found[19] that the yield is increased by introducing into the arc of an electric furnace the vapors of metals and metallic compounds, such as those of copper or iron and their salts.

W. Moldenhauer and O. Wehrheim[20] describe a method by which nitric oxide can be obtained by catalytic combustion of cyanogen compounds. Ammonia may also be used as the source of nitrogen, but the yield of nitric oxide is less than with cyanogen, and more attention must be paid to the condition of the catalyst and time of contact with it.

J. E. Bucher[21] proposes to produce alkali cyanides by the action of atmospheric nitrogen on alkali carbonate and carbon dissolved in iron, the iron acting as a catalytic agent. The alkali cyanide formed is removed from the reaction zone by distillation under diminished pressure.

The Deutsche Gold und Silber Scheide Anstalt[22] propose to pass gaseous mixtures containing nitrogen obtained by heating certain waste products such as "vinasses" through highly heated conduits lined with refractory material such as Dinas brick, fused quartz, or a fused mixture of zirconia and quartz which remains gas-tight and non-porous at the high temperature employed. It is said that practically the whole of the nitrogen is obtained in the forms of HCN and NH_3, the relative proportions of these varying with the raw material used.

In the process of Barzano e Zanardo[23] a mixture of nitrogen (say 60 per cent), hydrogen (32 per cent) and hydrocarbons (6 per cent) is raised to a high temperature, for example in the electric arc, and hydrocyanic acid absorbed by circulating the issuing gases through cooling and absorption apparatus. Sufficient nitrogen is added to maintain, with the hydrogen liberated, the concentration of these gases most favorable to the reaction.

Catalysis may be employed for the production of ammonia, not only from gaseous mixtures but also from solid organic nitrogenous compounds. F. Schreiber[24] proposes to act on the latter with contact masses containing hydrated iron oxide at temperatures below red heat. It is claimed that as much as 80 per cent of the nitrogen in pyridine and in cyanogen salts may be thus converted into ammonia, while ordinary destructive distillation yields not more than 20 per cent.

Production of Cyanogen Compounds from Gaseous Mixtures by Absorption with a Metallic Salt

The cyanogen contained in crude illuminating gas has for some years been utilized as a source of cyanides and cyanogen compounds on a commercial scale, as in the methods of Rowland[25] and Bueb[26].

L. Bergfeld[27] uses as purifying material dehydrated copper sulphate, or a mixture of salts, *e.g.*, alkaline earth sulphates or chlorides, which combine with NH_3 but not with H_2S, with metallic oxides capable of combining with H_2S. The mixture is treated with ammonia gas before use. The reaction is of the type:

$$H_2S + NH_3 + CaSO_4 \cdot NH_3 = CaS + (NH_4)_2SO_4$$

At the same time some SO_2 (which is fixed by the purifying material) and sulphur are also formed, thus:

$$SO_2 + H_2S = H_2O + SO_2 + S$$

When the purifying material is extracted it is heated, with regulated access of air, and ammonia liberated.

By gentle warming in presence of air, the ammonium sulphite deposited is rapidly oxidized to sulphate.

Cyanogen in the crude gas is fixed by the purifying material as cuprous ammonium cyanide. On heating with air this yields NH_3 and CO_2, and thiocyanate giving NH_3, CO_2 and SO_2. After passing the purifying material the coal gas may be further purified by leading it over alkali or alkaline earth sulphides, and if necessary over sodium amalgam.

C. A. Bergh[28] uses a solution of a zinc salt, containing also ferrous chloride, as an absorbent. The free acid formed is neutralized, and zinc sulphide and cyanide are precipitated, by addition of calcium carbonate, or some other sparingly soluble substance. This is added in quantity corresponding to the amount of H_2S and CN present. Iron remains in solution. By this method zinc is separated from iron and H_2S from CN by a single operation.

W. H. Coleman[29] passes coke-oven or other gases containing hydrocyanic acid through a tower packed with lumps of ferrous iron ore. A solution of sodium carbonate, or other suitable alkaline absorbent in solution or suspension, is circulated through the tower, and the resulting alkali or alkaline-earth ferrocyanicide liquor is treated for recovery of the ferrocyanide.

[19] Konsortium f. Elektrochemische Industrie, G. m. b. H. German Patent 268,277, July 1, 1911. Addition to German Patent 263,692.
[20] Zeit. f. Angewandte Chemie, vol. 27, p. 334, 1914.
[21] U. S. Patent 1,094,976. Assigned to Nitrogen Products Co.
[22] German Patent 255,440, Nov. 9, 1911. French Patent 448,772, Sept. 5, 1912.
[23] French Patent 456,826.
[24] German Patent 257,188, June 2, 1911.
[25] U. S. Patent 465,600, 1891.
[26] English Patent 9,075, 1898.
[27] German Patent 255,593, Aug. 24, 1910.
[28] German Patent 272,904, March 19, 1912.
[29] English Patent 27,908, Dec. 4, 1912.

Foreign Markets for American Chemicals*

BY DR. THOMAS H. NORTON
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Department of Commerce

Never before in our industrial history has the American manufacturer sought with more energy to gain a foothold in foreign markets. Never before have the opportunities for success in this field been so marked.

A titanic struggle is slowly sapping the strength of the chief European rivals of our country. Their power to maintain successful and prolonged competition is steadily diminishing, day by day.

Two nations, Germany and Austria-Hungary, are practically shut off from international markets. The ability to manufacture in other European nations is seriously impaired through the lack of workmen, through the difficulty of securing raw materials, through the more or less serious dislocation of the whole machinery for effecting the world's exchanges.

In the midst of this uncertainty this disorganization which prevails to a greater or less degree in the various European centers of production, it is a patriotic duty of American branches of manufacture to strive by every honorable means in their power to gain a permanent foothold in markets of all countries, neutral or belligerent.

What are the American manufacturers of chemicals doing to win new customers for their wares?

*A paper read at the meeting of the American Institute of Chemical Engineers held in connection with the First National Exposition of Chemical Industries in New York City on Sept. 22, 1915. Slightly abstracted.

In order to answer this question we must first establish the extent to which American chemicals were purchased in foreign countries prior to the great war. Next we can note the temporary effect of the war on our trade in chemicals. Finally, we should ascertain along what lines of least resistance an export trade in American chemicals can most easily and effectively be built.

AMERICAN EXPORTS OF CHEMICALS PRIOR TO THE WAR AND DURING THE WAR

Table I gives the principal items of export, during the fiscal year, ending June 30, 1914 and 1915; enumerated under the head of "Chemicals, Drugs, Dyes and Medicines" in the statistical reports of the Bureau of Foreign and Domestic Commerce:

TABLE I

Articles	1914		1915	
	Quantity	Value	Quantity	Value
Acids:				
Sulphuric, lb	12,131,750	125,892	46,771,510	516,436
All other	.....	357,035	.....	2,611,741
Alcohol, wood, gal	1,598,776	652,486	944,374	438,846
Baking powder, lb	2,725,964	750,274	3,376,780	881,879
Bark, extracts of, for tanning	.....	639,941	.....	2,226,457
Calcium carbide, lb	32,845,649	962,040	35,772,867	1,097,952
Copper, sulphate of, lb	7,375,775	330,007	10,238,808	445,580
Dyes and dyestuffs	.....	356,919	.....	1,177,925
Ginseng, lb	224,605	1,832,686	103,184	919,931
Lime, acetate of, lb	68,160,224	1,560,933	24,673,247	486,405
Medicines, patent or proprietary	.....	6,721,978	.....	7,130,379
Petroleum jelly, etc	.....	661,889	.....	838,842
Roots, herbs, and barks, crude, not mixed	.....	513,071	.....	470,090
Soda salts and preparations	.....	.....	.....	3,141,022
Sulphur or brimstone, crude, tons	110,022	2,018,724	48,391	885,756
Washing powder and fluid, lb	12,761,958	535,635	14,695,317	635,476
All other	.....	9,019,582	.....	22,476,269
Totals	.....	$27,079,092	.....	$46,380,986

The variations in trade are somewhat more sharply marked if comparison is made of the exports during the months of June, 1914 and 1915. This is illustrated by Table II.

TABLE II.—EXPORTS DURING THE MONTH OF JUNE

Articles	1914		1915	
	Quantity	Value	Quantity	Value
Acids:				
Sulphuric, lb	647,498	5,948	5,931,208	63,516
All other	.....	23,102	.....	354,591
Alcohol, wood, gal	165,463	62,769	58,508	30,108
Baking powder, lb	249,446	74,634	320,953	85,142
Bark, extracts of, for tanning	.....	69,834	.....	506,289
Calcium carbide, lb	1,996,632	57,978	3,251,754	92,633
Copper, sulphate of, lb	281,445	12,265	144,268	9,115
Dyes and dyestuffs	.....	40,580	.....	204,732
Ginseng, lb	31,580	244,145	9,088	77,033
Lime, acetate of, lb	6,908,360	112,743	2,589,641	73,950
Medicines, patent or proprietary	.....	521,309	.....	780,811
Petroleum jelly, etc	.....	50,094	.....	88,923
Roots, herbs, and barks, crude, not mixed	.....	39,057	.....	77,149
Soda, salts and preparations	.....	.....	.....	684,355
Sulphur or brimstone, crude, tons	9,342	173,125	1,637	35,088
Washing powder and fluid, lb	1,508,698	59,402	1,322,231	59,715
All other	.....	876,409	.....	3,114,756
Totals	.....	$2,423,203	.....	$6,337,906

It will be noticed that the fiscal year recently elapsed, has witnessed notable increases in amount exported for the following articles: Sulphuric and other acids, calcium carbide, dyes and dyestuffs, petroleum jelly and other articles.

Decreases are noted in the case of wood alcohol, copper sulphate, ginseng, calcium acetate, sulphur.

There is little variation in the amount exported of baking powder, medicines, roots and washing powder.

As a whole the export of chemicals for 1915 shows an advance in value of 72 per cent over that of 1914.

The export of June, 1915, is 161 per cent greater than that of 1914.

The classification of the Department of Commerce does not include explosives, which increased in value from $6,272,000 in 1914, to $41,476,000 in 1915. It does not include also the heavy exports of cement, ink, mineral oils, paints, pigments, and varnish, perfumery, soap and a few other items, closely allied to the chemical schedule, but in which the variations in the volume of export were not of material importance.

It is quite evident that apart from munitions, the war has brought about a very pronounced increase of our chemical exports both in volume and in value. It is unfortunately impossible at present to have the complete data now being collected so that we may gain an adequate idea of the geographical distribution of the increase in exports during the past year. It suffices for the moment to note that the existing international conditions have very distinctly favored the expansion of the foreign market for American chemicals.

MARKETS OPEN TO AMERICAN CHEMICALS

And now, how can we most effectively build up an export trade in chemicals?

Evidently the existence of a world-wide war presents peculiar opportunities which can be utilized with perfect freedom, in the firm conviction that no ethical law is violated. With the friendliest of feelings toward Briton and Teuton, and the allies of both, we recognize that each of these two countries, normally so prominent in the export of chemicals, is now unable to meet fully the normal demands upon its productive capacity. A strong effort, on the part of American manufacturers of chemicals, to fill these demands is undoubtedly dictated by the circumstances, and it is likewise our duty to aim to build up permanent trade relations in those fields. It is most deplorable and unfortunate, from the standpoint of humanity, that such intense bitterness is awakened by the great conflict across the water. For years it will influence currents of trade; on the advent of peace, entire nations will apparently refuse to purchase the products of certain other nations.

The existence of such a factor of hostility and antagonism between nations hitherto closely related in international trade, is most regrettable. We can but hope that it eventually will disappear. In the meantime without encouraging any act on our part, we are legitimately free to do our best to meet the demands which may be made upon every branch of our national industry, and presumably upon our chemical industry, to an extent hitherto unknown.

Let us note what chemical products of the leading

TABLE III.—IMPORT OF CHEMICALS INTO DIFFERENT COUNTRIES

EUROPE			
Austria-Hungary	$20,386,000	Portugal	$1,864,000
Belgium	28,814,000	Roumania	1,191,000
Bulgaria	718,000	Russia	16,081,000
Denmark	3,897,000	Finland	306,000
France	32,900,000	Servia	245,000
Germany	79,394,000	Spain	10,224,000
Greece	1,180,000	Sweden	4,005,000
Italy	14,647,000	Switzerland	8,621,000
Netherlands	132,679,000	United Kingdom	75,113,000
Norway	1,039,000		
NORTH AMERICA			
United States	$78,207,000	Costa Rica	$113,000
Canada	10,933,000	Cuba	2,081,000
British West Indies	523,000	French Colonies	237,000
Mexico	4,688,000		
SOUTH AMERICA			
Argentina	$4,466,000	French Guiana	$27,000
Brazil	4,293,000	Peru	925,000
Chile	1,657,000	Uruguay	784,000
British Guiana	409,000		
ASIA			
China	$10,804,000	Japan	$13,536,000
India	9,245,000	Korea	202,000
Dutch East Indies	5,514,000	Siam	261,000
French Indo-China	1,149,000		
OCEANIA			
Australia	$589,000	New Zealand	$1,733,000
AFRICA			
British South Africa	$987,000	Tunis	$238,000
Mauritius	590,000	Egypt	3,307,000
Algeria	1,645,000		

European countries have entered most conspicuously into international trade.

IMPORTS OF CHEMICALS INTO THE VARIOUS COUNTRIES

Table III shows the value of the imports of chemicals, drugs, dyes and fertilizers, into each of the various countries, which keep careful statistics as tabulated for the year 1906.

Summarized, the countries of the world purchase chemicals, drugs, dyes and fertilizers to the following extent:

Europe	$433,304,000
North America	96,782,000
South America	12,561,000
Asia	40,731,000
Oceania	2,322,000
Africa	6,767,000
	$592,467,000

To this international market the United States brought for sale in 1906 wares to the value of about $41,000,000, or 7 per cent of the whole.

Such is the field in which our manufacturers of chemicals are to extend their trade. It is the trade with Latin America, with Asia, and with Oceania that they should seek to win. The potential purchasing power of these portions of the globe amounted in 1906 to over $74,000,000. Unquestionably in Europe itself markets will open to us which have hitherto been closed.

The Empire of Germany has contributed to the international traffic, chemical wares valued at $111,000,000 annually, or 17 per cent of the entire amount. The United Kingdom contributed chemicals valued at $63,019,000, or 11 per cent of the total amount.

The markets which have hitherto secured their supplies chiefly from Germany are naturally the ones, under existing circumstances, in which the most earnest efforts should be made to cultivate new trade relations.

It would lead me too far to analyze in detail the markets for chemicals in the non-European countries, more accessible to our commerce. The detailed statistics of German exports show, however, very clearly the great extent of the territory which at present must seek its supply of chemicals from new sources.

I would, therefore, urge upon the manufacturers of chemicals who distinctly desire to enlarge their foreign connections and establish themselves solidly and firmly in the markets of the countries to the south and west of our borders, a most careful and detailed study of the import statistics of Latin America and Asia.

In frequent cases, where European wares have dominated the world's markets, our own production has been restricted and remained in a half-developed state.

Here there is abundant reason for us to make a valiant effort to break out from the chrysalis-like condition, unfold our wings to the fullest extent and meet not only the demands of the home market, but sally forth into the markets of the world. Such a bold and vigorous line of action is dictated more especially when the raw material required is found in abundance within our own borders.

Two such fields of industrial effort and industrial evolution are, at the present moment, pre-eminently worthy of our notice. Potash and dyestuffs are terms haunting the waking hours and banishing slumber from thousands of manufacturers between the Atlantic and the Pacific. The fertility of immense tracts of our land will sadly suffer unless means are found to replace the supplies of potash salts hitherto received from the mines of Germany.

Hundreds of the textile mills throughout the eastern half of the republic are facing a dyestuff famine, resulting from the complete cessation of imports of artificial colors from Germany since the middle of March last. This threatens a more or less complete stagnation in production. It involves under the most favorable conditions, such a dislocation of technical and commercial relations along the whole chain of connecting links, between the producer of textile fibers and the ultimate consumer of knitted or woven fabrics, that the daily loss, direct and indirect can be measured only by hundreds of thousands of dollars.

POTASH

In the case of potash, it is an economic absurdity that the farmers and manufacturers of this country should be so absolutely dependent upon a single foreign source. The painstaking, exhaustive studies of the Bureau of Soils in the Department of Agriculture show beyond the shadow of a doubt that the vast amount of potash stored annually in the boundless beds of kelp, floating off our Pacific littoral, can amply meet the world's demands. My own studies on this subject reveal a handsome margin of profit, should the attempt be made, on a grand scale, to garner this valuable crop, and replace for use as a fertilizer, the $10,000,000 worth of potash which we bring across the ocean from the mines of Stassfurt. The methods of extracting from kelp the technically pure potassium chloride to serve as a starting point for the manufacture of a large variety of salts of potash employed in the arts has now been so far advanced that at an early date we may witness the complete disappearance from our markets of foreign salts in this category.

Highly perfected now are, also, the methods for extracting in a soluble condition the potash content of our vast deposits of feldspar. Of exceptional interest is the recent process for releasing from its rocky fetters the potash in the form of the carbonate, the most convenient salt to use in taking up the manufacture of the other compounds of potassium as well as in the glass industry.

The progress in the utilization of our Western deposits of alunite is also noteworthy. Large quantities of potassium sulphate are now shipped regularly from Marysvale, Utah. The recent discovery of enormous deposits of alunite in the State of Washington, adjacent to tidewater, is of great moment, as the question of freights is notably simplified.

Of great interest is the process recently perfected by a young chemist of this city for rescuing from distillery waste the notable quantities of potash at present allowed to go to waste.

The current daily loss throughout the United States in distilleries employing molasses as raw material is estimated at 106 tons of pure K_2O. This is now transformed into a dry powder containing over 9 per cent of potash and a considerable amount of nitrogen. It serves admirably for the manufacture of composite fertilizers. A large plant is now being equipped at Boston for the utilization of this distillery waste product on an extensive scale.

In view of all this may I not confidently look forward to the early date when the production of American potash will have reached a point that permits a large export after having met all domestic demands? Within a decade or two this country should easily compete in the world's markets with the salts of Stassfurt, which hitherto has been practically the only source.

DYESTUFFS

Equally hopeful is the outlook for the ultimate solution of our dyestuff problem.

When it became evident that a "color famine" was imminent, the situation was quickly sized up by the little band of American manufacturers of artificial colors.

With true American pluck and enterprise, emancipation from dependence upon foreign-made intermediates was declared the slogan. At an expense of hundreds of thousands of dollars the necessary plant was erected to transform American benzol, toluol, naphthalene, etc., into the numerous intermediaries directly required for color production. Not an hour was lost in completing the new equipment. To-day one establishment is manufacturing nearly 60 per cent more than was the case in July, 1914; another has trebled its output of that date.

The movement has not been limited to an enlargement of existing works. A large group of new firms has sprung into existence and is actively engaged in the production of coal-tar intermediates, notably of aniline, which can also be used directly in the production of aniline black on hosiery and yarn.

Thomas A. Edison is a brilliant example of what Yankee foresight and intelligence can accomplish in such a field. Consuming normally large amounts of carbolic acid in the manufacture of the records for his phonograph, he suddenly faced a crisis. The price of the article had soared from 10 cents per pound to $1.50, and but little could be secured at that rate. Promptly Mr. Edison assured an adequate supply of benzol, the primary coal-tar "crude," from which carbolic acid can be prepared synthetically. This was accomplished by erecting at considerable cost the requisite "scrubbers" for the removal of benzol from the waste gas of by-product coke ovens. He was then in a position to embark extensively upon the manufacture of carbolic acid. Finding the venture so successful, he constructed the necessary plant for the manufacture of aniline. This proved to be also most profitable.

In solving so simply and effectively two leading phases of the coal-tar problem, Mr. Edison has blazed the trail for other daring pioneers, and has shown how simple is the primary series of operations necessary to build up a self-contained American dyestuff industry. There are now quite a number of well-financed companies which are daily increasing the volume of the output of coal-tar intermediates and which are turning their attention to the manufacture of finished dyestuffs. Chemists, consumers, and economists have vigorously attacked the entire problem. There is an insistent inquiry, "Why are we not making ourselves all of the colors required by American consumers of dyestuffs?"

The Department of Commerce has taken an active interest in the working out of the problem. It has done all in its power to stimulate and encourage the efforts now directed to build up an independent, self-contained American coal-tar chemical industry. It has collected and disseminated the requisite information for those planning to enter the new field. It has carefully and exhaustively studied the question of how far existing law can protect the young industry against unfair competition on the part of foreign rivals, when normal international relations are restored.

Gradually the decisive factors in the situation have been determined and outlined. They may be summarized as follows:

The United States possesses all the needed raw materials in abundance—in such amount that it could meet the demands of the world's dyestuff industry. It offers the largest existing market for consumption of dyestuffs.

Enterprise, inventive talent, and technical ability are present in abundance.

Capital is ready to embark in the new field in ample amount, and is daily being invested.

On the other hand, we lack the few skilled, experienced captains of industry, well-trained in this special field, and thoroughly well-equipped to organize and conduct the manufacture of colors on essentially the same basis as now exists in directing the gigantic factories on and near the Rhine.

There is also some hesitation on the part of capital to build up the industry on a magnificent scale, fully commensurate with the country's needs, until there is absolute certainty that laws will find their way to our statute books capable of effectually preventing any attempt to destroy the young industry on the part of foreign competitors.

This is, in fact, the one great IF, which for the moment blocks to some extent the rapid and healthful expansion of the domestic industry. With or without the leadership of men equal in technical and scientific equipment to the brilliant galaxy of those directing the European factories, we are bound to have our independent American color industry. The moment is impatiently awaited when the President of this republic shall affix his signature to a law making as impossible in foreign trade as it is now in domestic trade any attempt to crush, stifle and throttle a new industry on the part of competing rivals beyond the seas. When this moment arrives, capital in abundance is ready to back American enterprise in swiftly but surely laying the foundations for a permanent American coal-tar color industry. It may take a year or two to furnish one-half of the artificial dyestuffs now in current use; it may take four or five years before nine-tenths of the colors now regularly used in American textile and other factories are made from American benzol, toluol, naphthalene, phenol, anthracene and carbazol. But the day is coming as certainly as the sun will rise to-morrow morning from the waves of the Atlantic.

It is most refreshing to note the utter indifference to minor side-issues manifested by the men who are determined to build up this new industry. But a few years ago discussion would have centered about the tariff. To-day the men who are ready to finance a color industry, or to throw into it the best of brain and nerve, are asking simply for a fair show—to prevent a competitor from hitting below the belt. The vast multitude depending directly or indirectly upon an abundant supply of coloring materials are fast losing patience with the class of publicists who fold their hands in the face of a profound industrial crisis, and grumble because the determined and persistent pressure brought to bear by our State Department has not yet succeeded in inducing our friends in Berlin to allow the free exportation of dyestuffs to our ports. They show as little interest in those who murmur, "Raise the tariff and it will be possible to plan for a genuine American color industry." Their sympathies are with the red-blooded men of action who have worked out the details of this most intricate of problems, recognize fully its manifold difficulties and the multitude of obstacles in the path, and yet are ready for the fray.

I cannot but admire men of the type of J. F. Schoellkopf of Buffalo, the pioneer in this branch, whose name will go down in our economic history as the father of the American coal-tar chemical industry. With what energy and strategy during the past twelvemonth has he multiplied the working features of the magnificent plant on the shores of Lake Erie, freed himself technically from all dependence in the future on foreign-made materials, concentrated his efforts on a few of the staple, most essential colors, and thereby vastly magnified his output. Such wisdom and resoluteness have meant salvation from heavy loss to many a mill man, hesitating whether he should close the doors and dismiss his operatives.

A year ago, a modest color factory was in operation in Brooklyn, sadly hampered by the sudden inability to

secure the customary intermediate compounds from across the sea. One night last November it was destroyed by an explosion, accompanied by sad fatalities. Did Dr. William Beckers decide to wait for further developments in the great struggle to our east, or for congressional action, before he laid his plans? Not he! A million dollars were promptly expended in new constructions and in the requisite mechanical equipment for eliminating all dependence henceforth on material from European works. To-day he also is able to contribute bravely his share towards lessening the hardships of the textile industry.

I might mention, in passing, the notable enlargement of the coal-tar dyestuff works in the great establishment of Heller & Merz at Newark, the spacious new buildings of the neighboring Central Dyestuff Works, and the noteworthy effort within the past few weeks to materially broaden the scope of the Consolidated Dye Works, in Newark, under the energetic direction of the Hon. Herman A. Metz, whose patriotic desire to contribute his part in building up an American dyestuff industry is equalled only by his achievements of a year ago in securing for our users of colors ample supplies from Europe when stocks were dangerously low.

I can dwell upon these aspects of the dyestuff situation in but a hasty and cursory manner. I cannot, however, close without referring briefly to promising and fascinating efforts to create an American dyestuff industry, in a new and very literal sense of the word. Two new projects have interested me extremely. The appearance at this exposition of the Pearsite and the Petracine colors may possibly mark new starting points in the evolution of the color industry. . . .

And now, let me revert to my original theme. May we not all look forward with a fair measure of confidence to the exposition of 1925, when the directors of American coal-tar chemical works will report to us their sales of American-made dyes in the world's markets?

What has been accomplished with the products of our iron mines and our pine forests, as well as with the many triumphs of American mechanical genius, can surely be attained in the field of coal-tar chemistry by a similar use of resoluteness and energy, supported by the helpful action of the nation's lawgivers, in granting full protection against unfair practices on the part of foreign competitors.

Centrifugal Pumps.—The Lea-Courtenay Company, Newark, N. J., has issued catalog H-2, containing illustrations and descriptions of their centrifugal pumps of the turbine type, double-suction, single and multi-stage types and single suction, multi-stage type for varied lines of work.

The **Pensacola Tar & Turpentine Co.** of Gull Point, Fla., has sent us its latest list of oils for flotations, comprising eight different oils. This company makes a specialty of producing oils for flotation purposes. "It seems that from 10 to 30 per cent of pine products are desirable, if not quite necessary, on most ores."

The **Specific Heat and Heat of Fusion of Ice** have been determined by the Bureau of Standards at the request of the refrigeration industries. The results are given in Paper No. 248, the authors being H. C. Dickinson and N. S. Osborne.

The **Bureau of Mines** has issued Bulletin 94, United States Mining Statutes Annotated, by J. W. Thompson. This is a large work in two volumes and shows the status of every Federal mining law, both relating to metal mining and coal, oil, and phosphate. It may be had for $2.50 by applying to the Superintendent of Documents, Government Printing Office, Washington, D. C.

Recent Chemical and Metallurgical Patents

Iron and Steel

Electric Steel Refining.—If the electric furnace is to become of widest use for the manufacture of large-tonnage steel products (rails, structural steels, etc.), it must be in a process in which electric-furnace refining succeeds Bessemer converter or open-hearth treatment, and it is of utmost importance to reduce the combined cost of such a combination process to a minimum. The principal problem of any such duplex process is to determine the exact point where to stop one step and begin the next step. In ordinary steel manufacture the manganese contained in the pig iron is almost wholly lost through oxidation in the Bessemer converter or open-hearth furnace. Mr. WILLIAM R. WALKER of the U. S. Steel Corporation avoids this loss by stopping the heat of the oenverter or open hearth while a major portion of the contained manganese (above 0.1 per cent) is still present in the metal. The metal is then tapped and fed into an intermediate mixer which equalizes the manganese contact. From this mixer charges of desirable size are taken to the electric furnaces in which the metal is deoxidized, largely through the action of manganese. (1,155,849, Oct. 5, 1915.)

Alloys

Alloy of Platinum and Osmium.—A substitute for platinum-iridium or "hard platinum" is patented by Dr. FRITZ ZIMMERMANN of Newark, N. J., the patent being assigned to Baker and Company. The limited supply of iridium and its high price have created a demand for another hard alloy. By a series of tests it was found that the addition of osmium to platinum greatly increases the hardness. The percentage varies between ½ of 1 per cent to 10 per cent. Alloys with 10 per cent are only workable with difficulty. As far as hardness is concerned, one part of osmium is equal to two and one-half parts of iridium; the tensile strength is high, and the alloy is ductile and is also more resistant to the action of acids than platinum-iridium. The alloy of 98 per cent platinum and 2 per cent osmium can be used for jewelry work, being hard and tough, while alloys containing 10 to 6 per cent osmium will replace alloys containing 15 to 25 per cent of iridium for contact points in electrical apparatus. The platinum and osmium must be refined to a high degree of purity to remove impurities. The natural platinum which contains osmium, copper and iron cannot be used for this purpose. (Original 1,055,119, March 4, 1913; reissue 13,691, Aug. 10, 1915.)

Electric Furnaces

Abrasive for Grinding Steel.—An electric-furnace abrasive of oxides of aluminium, magnesium, and titanium is patented by Dr. HERBERT T. KALMUS of Brookline, Mass., the patent being assigned to the Exolon Co., Cambridge, Mass. Abrasives consisting essentially of alumina are said to have been found too brittle for certain classes of steels, the cutting edges of the grains failing under compression before they become dulled. Experiments showed that pure alumina tends to crystallize with a coarse structure which it is very difficult to prevent by any of the practical devices for operating electric furnaces. Magnesium and titanium oxides in the proportion of their molecular weights, when fused with alumina in the right proportion, give a resulting product of very fine-grained, crystalline alumina, the spaces between and surrounding the individual crystals being filled with magnesium aluminate, magnesium titanate, and eutetics of these with alumina. This product possesses the proper qualities to give efficient cutting action on hard steels and other hard

metals. Neither the oxide of titanium nor the oxide of magnesium alone gives the desired combination of abrasive properties.

In commercial practice emery, or aluminous material, containing the oxides of magnesium and titanium in the right proportions, is mixed with carbon in sufficient proportion to reduce all impurities, charged into an electric furnace and fused. The stationary arc-type in which the electrodes are gradually raised is preferable. The iron oxide and silica content should be gaged to have a ratio of six to one in order to produce ferrosilicon as a by-product. By the fusion, a pig of segregated metals, resulting from the furnace reduction, is formed at the bottom of the furnace and a pig of abrasive material is formed in the body of the furnace above the metal pig; these may be allowed to cool in the furnace, then separated. An abrasive was prepared from emery which contained 95.5 per cent Al_2O_3, 1.5 per cent MgO, and 3 per cent TiO_2. This product was hard, tough, fine-grained, and practically insoluble in water and acid solutions. When working with hard varieties of steels it is desirable that the abrasive should not contain more than 3 per cent or less than one-half of 1 per cent magnesium or titanium oxide. Iron oxide and silica should not be present in excess of 1 per cent. The temperature of the furnace is kept high enough to reduce the iron oxide and silica, but below the reduction temperature of alumina, so as to prevent the formation of sub-oxides or carbides. This process is said to make possible the use of domestic emery ores, which had heretofore been found objectionable owing to their magnesium content. Usually the emery ores used have been foreign, which were practically free from magnesium oxide. (1,149,064, Aug. 3, 1915.)

Calcium Carbide from Carbide Fines.—When carbide fines have been utilized for directly remelting in an electric furnace and causing the material to solidify in masses, it has been found that the product was not of good quality, giving a low yield of acetylene. This was found to be due to a loss of carbon during the remelting, and the fines are difficult to smelt owing to their irregular conductivity. In a patent of HERMAN L. HARTENSTEIN of Constantine, Mich. (assigned to Continental Investment Co., Duluth, Minn.), it is proposed to mix the carbide fines with finely divided coke, charcoal or a suitable grade of coal and treat this mixture in an electric furnace. This can be accomplished in the ordinary types of electric furnace in much the same manner as calcium carbide is ordinarily made. The amount of carbon employed in the mixture should be enough to reduce moisture that is present to hydrogen, carbon dioxide to carbon monoxide, etc. In this manner reduction of the calcium carbide by oxygen or oxides is prevented. There should also be enough carbon present to transform any other calcium compounds present, like calcium hydrate, oxide, carbonate, etc., into calcium carbide. In practice the waste carbide or carbide fines are analyzed, since the composition varies greatly with age, state of fineness, etc. The amount of unchanged carbide is determined and also the amount of oxidants capable of affecting changes in the carbide. After having determined this the necessary carbon and carbide fines are mixed and fed into an electric furnace, where the mixture is heated and reduced to a molten condition. It may then be allowed to cool in the furnace or be tapped. The carbide is claimed to be of high grade and much superior to the dust used in its production. (1,152,506, Sept. 7, 1915.)

Preventing Blue Powder in the Electric Reduction of Zinc Ores.—A patent for preventing sulphidization of zinc vapors in the electric reduction of zinc ores has been granted to Mr. WOOLSEY MCA. JOHNSON of Hartford, Conn., and is assigned to the Continuous Zinc Furnace Company, Hartford, Conn. It is of interest in connection with the puzzling problem of preventing the formation of blue powder in the condensation of zinc reduced in electric furnaces. The presence of sulphur in the free state, as carbon disulphide, sulphur dioxide or trioxide causes a partical sulphidization of the zinc vapor, forming a coating which prevents the zinc globules from coalescing into liquid zinc. In this process the ores are first calcined, the charge being so proportioned as to give a resulting product analyzing about as follows: 30 per cent Zn, 10 per cent Pb, 2 per cent Cu, 15 per cent Fe, 8 per cent SiO_2, 4 per cent CaO, 1 per cent MgO, 3 per cent S. The roasting temperature is about 950 deg. Cent., and the conditions such that sulphates other than those of barium, calcium, and lead are decomposed.

The hot calcined product from the roasting operation is mixed with 15 to 20 per cent of soft coal. The fluxes for the final electric furnace treatment may also be added at this stage. The mixture is then fed into a preheater furnace of the continuous coal or gas-fired type such as the McDougall. In this preheater the $PbSO_4$, $BaSO_4$, Fe_2O_3, CuO are reduced to PbS, CaS, BaS, Fe and iron suboxide, and Cu. No reduction of ZnO should take place.

Other reducing agents might be used in place of carbon, such as hydrogen, carbon monoxide or hydrocarbons, for instance.

The hot product from the preheater is then charged, without access to the air into a continuous electric furnace, where the following reactions take place:

$$ZnO + C = Zn + CO$$
$$ZnO + Fe = Zn + FeO$$
$$ZnS + Fe = Zn + FeS$$
$$ZnS + Cu_2 = Zn + Cu_2S$$

The iron is absorbed by the slag, the sulphides of iron and copper are absorbed by the matte. Lead sulphide is reduced to Pb by the iron or copper. The sulphur of the BaS and CaS is taken up by the Fe and Cu, and the Ba and Ca enter the slag as silicates. A large excess of metallic particles is continuously descending through the charge and slag into the matte. These metallic particles effect the desulphidization of vapor, charge and slag, and the vapor leaves the furnace in the right condition for condensing to liquid zinc. It is, of course, necessary to use the right temperature, for if the furnace were heated as high as 1350 or 1400 deg. C., carbon disulphide, SO_2 or SO_3 might form, and the matte might also be slightly decomposed. (1,150,271, Aug. 17, 1915.)

Preventing Punctures in Flame-Arc Furnaces.—A method of preventing punctures in flame-arc furnaces is patented by EINAR TROYE of Christiania, Norway. It consists in allowing an air space between the outer iron cover of the furnace and the brick lining. Air is passed through this space at a suitable pressure and may later be used in the furnace if desired. More than one air space could be used with walls of asbestos interposed between them. This method is claimed to allow of a considerable reduction in the thickness of the brick wall and to make a completely puncture-free furnace, also avoiding any current loss in the earth. (1,148,343, July 27, 1915.)

Boron Nitride.—A process for making boron nitride is patented by Dr. GEORGE WEINTRAUB of Lynn, Mass., and assigned to the General Electric Co. In this process borax and a cyanogen compound such as a cyanide or ferrocyanide are finely powdered and mixed and then heated to 2000 deg. C. in an electrical resistance furnace. All products such as carbonates, cyanates,

and the excess of borax or boric anhydride are volatilized and boron nitride remains. The process is continued until no more fumes are evolved and a white stable product is left. The yield is 30 per cent and upwards of the theoretical. (1,135,232, Apr. 13, 1915.)

Electrolytic Furnaces

Alkali and Alkaline-Earth Metals.—An electrolyte of cyanide or cyanamide for the production of metallic sodium, calcium, etc., in an electrolytic furnace is patented by Mr. CHARLES E. ACKER of New York and assigned to the Nitrogen Company. According to a process of Ashcroft (801,199, Oct. 10, 1905) fused sodium chloride is electrolyzed with a molten lead cathode, producing an alloy of lead and sodium. In the Ashcroft process this lead-sodium alloy was then used as the anode in a secondary electrolytic furnace which had sodium hydroxide or chloride as an electrolyte and an iron or nickel cathode. The metallic sodium liberated at the cathode and rose to the top of the electrolyte. The present patent proposes to use a secondary electrolyte of sodium or potassium cyanide or cyanamide, claiming high efficiency at a convenient temperature, and an improved product. (1,142,220, June 8, 1915.)

Synopsis of Recent Chemical and Metallurgical Literature

Gold and Silver

Notes on Homestake Metallurgy.—A paper by ALLAN J. CLARK supplementing a former paper before the Inst. of Min. & Met., London (*Transactions*, Vol. XXII, page 68, 1912-13), was presented at the A. I. M. E. meeting in San Francisco. The present paper deals with changes that have been made in Homestake metallurgy since the former paper was written. A flowsheet is given in Fig. 1.

A new mortar recently adopted retains the old inside lines so effective in maintaining a rapid discharge. All the front above the screen rest has been cut away; also a considerable portion of the back. The result is greater accessibility and increased safety to men when changing iron—it permits the use of longer bossheads and simplifies the care of feeders. A small chip tray of 4-mesh screen rests above the discharge screen and collects floating particles of wood. These are collected and burned, the ashes having a value of $300 per ton.

Table I shows the tendency of the unoxidized ore to amalgamate less readily than was the case in earlier years, and the tendency toward recovery of amalgam farther from the battery.

TABLE I.—COMPARISON OF AMALGAMATION RESULTS ON ORES OF DIFFERENT PERCENTAGES OF SULPHIDES

Column I. All mills, three-month period in 1910.
Column II. One mill, crushing unoxidized ore exclusively, three months, 1915.

Of the Total Recovery by Amalgamation, there was Recovered from:	I. Per Cent	Cumulative Per Cent	II. Per Cent	Cumulative Per Cent
Batteries	49.4	49.4	35.6	35.6
First-row plates	37.5	86.9	42.9	78.5
Second-row plates	4.4	91.3	8.1	86.6
Third-row plates[a]	2.3	93.6	3.5	90.1
Fourth-row plates	0.9	94.5	2.0	92.1
Skimmings[b]	4.0	98.5	6.9	99.0
Trap sands	1.5	100.0	1.0	100.0
Percentage of ore value	....	71.7	....	69.7

[a] Only two mills (440 stamps) equipped with a fourth row of plates.

[b] The "skimmings" of the above table are recovered from re-treatment of the foul amalgam, sulphide particles, etc., removed from the cleanup sink during the cleanup of the chuck-block and plate amalgam.

In an effort to determine what relation, if any, exists between the amount of quicksilver fed to the batteries, the amount of bullion recovered, and the grade of the ore crushed, the records of all six mills were tabulated over a period of one year. While the experiment was without decisive results, the results of four mills, including those crushing ore of the two extremes in value, coincided reasonably well with a curve represented by the equation:

$$T = \frac{8.5\,B - H}{H}$$

when

T = Value of ore (dollars per ton).
H = Troy ounces of quicksilver fed to batteries.
B = Troy ounces crude bullion ($16 per oz.) recovered.

A detailed analysis of lost time in the stamp mills shows a percentage of 1.07.

COST OF STAMP MILLING

	Stamping	Amalgamating		Total
		Normal Charges	Rebuilding Plate House	
Operating labor	$0.0895	$0.0164	.....	$0.1059
Other labor	0.0033	.....	$0.0064	0.0097
Power	0.0457	.....	.....	0.0457
Machinery	0.0628	.....	.....	0.0628
Water	0.0315	.....	.....	0.0315
Sundry supplies	0.0097	0.0036 quicksilver 0.0042 silver plating 0.0003 miscellaneous	0.0059 silver plating 0.0018 lumber	0.0255
Total	$0.2425	$0.0245	$0.0141	$0.2811

Power at $30 per horsepower year; quicksilver at 50c. per pound; castings, 2½c. per pound; mill labor, $2.97 per 8-hr. shift.

REGRINDING PLANT DATA

Mill Number	1	2	3	4
Manufacturer	Denver Engr. Works	Allis-Chalmers Co.	Allis-Chalmers Co.	Hardinge Conical Mill Co.
Dimensions, feet	5 by 14	5 by 18	5 by 18	6 by 6
Speed, rev. per min.	27.0	28.5	28.0	26.5
Actual horsepower (motor input)	32.0	42.0	42.0	27.0
Fed from	Dewatering cone	Dorr classifier	Dorr classifier	Dewatering cone
Tons fed per day	98.0	138.0	133.0	93.0
Pebbles per ton	1.40	1.24	1.38	1.71
Tons to pass 100 mesh	41.0	52.0	49.0	34.0
Tons to pass 100 mesh per horsepower	1.28	1.24	1.17	1.26

REGRINDING PLANT: OPERATING COSTS FOR 1914

	Cost per Ton Fed to Tube Mills	Cost per Ton Reduced to Pass 100-Mesh Sieve
Labor	$0.0496	$0.1289
Pebbles and liners	0.0259	0.0673
Renewals, mills and cones	0.0074	0.0193
Machine-shop service	0.0037	0.0096
Silver plating	0.0077	0.0200
Sundries	0.0029	0.0075
Power	0.0292	0.0759
Total	$0.1264	$0.3285

Tons fed to mills, 152,106. Tons ground to pass 100-mesh sieve, 58,605. Cost of regrinding, per ton crushed in stamp mills, $0.0121.

Classification and aeration are two essentials for successful sand treatment. Aeration is necessary to prevent ferrous compounds removing oxygen from the solutions, and is accomplished by forcing air under slight pressure below the canvas filter. Laboratory tests indicate that on an average 75 cu. ft. of oxygen is absorbed by a ton of ore before its reducing action is corrected.

Although it had been recognized that high protective alkalinity was detrimental, it had been considered impossible to dispense with it entirely, or practically so. Eventually this was done, with improvement in extraction and decreased consumption of cyanide. These results were partly due also to another change made about the same time. Solutions of two strengths are used, that stronger in cyanide being used earliest in the treatment of a charge. When these solutions appear as

effluents, one portion is precipitated and the other brought to full working strength by adding cyanide, and returned to the extraction of another lot of sand.

"This custom is by no means unusual, yet wherever it is used the procedure seems to be to maintain the stronger solution at a fixed content of cyanide and to allow the weaker to vary in strength according as the varying losses in treatment may determine. This is wrong in principle. The critical strength is that below which the weaker solution will no longer dissolve its quota of gold, or, if dissolving it, will no longer freely yield it to precipitation. If the strength is greater than this, we may confidently expect some cyanide to be destroyed without giving compensatory service. In such circumstances, if the maximum working strength is reduced, the weaker solution will be automatically restored to the lowest economic strength; if it falls below this, a temporary increase in the maximum strength will restore it. In other words, cyanide should be added to the *strong* solution in accord with the determinations of strength made on the *weak* solutions. Thus, operating with a strong solution of variable strength and a weak solution also variable, but never far from its effective limit, it may be anticipated that little cyanide will be needlessly expended."

No. 1 SAND PLANT: OPERATING COSTS FOR 1914. TONS TREATED, 598,043

	Operating Labor	Other Labor	Power	Chemicals	Misc.	Total
Superintendence	$0.0081	.....	.....	.....	.....	$0.0081
Assaying	0.0033	.....	.....	$0.0004	$0.0006	0.0043
Transportation	0.0010	.....	.....	.....	0.0001	0.0011
Neutralization	0.0034	.....	$0.0002	0.0093	.....	0.0129
Classification	0.0006	$0.0002	0.0007	.....	0.0008	0.0103
Treatment	0.0293	0.0011	0.0054	0.0541	0.0021	0.0920
Precipitating and pumping solutions	0.0055	0.0005	0.0005	0.0046	0.0006	0.0117
Heating	0.0007	.....	.....	.....	0.0041	0.0048
Refining	0.0015	.....	.....	.....	0.0022	0.0037
Miscellanies	0.0019	0.0009	0.0005	.....	0.0024	0.0057
Repairs[a]	.....	0.0121	.....	.....	0.0072	0.0193
Power from H. M. Co	.....	.....	0.0033	.....	.....	0.0033
Total	$0.0632	$0.0148	$0.0106	$0.0684	$0.0202	$0.1772

[a] Includes only larger items of repair work, necessitating the labor of a crew of carpenters.

Unit consumptions per ton of sand treated: Sodium cyanide, 0.257 lb.; zinc dust, 0.061 lb.; lime, 2.48 lb.; power, 1.09 kw.-hr.

Treatment of slime in the Merrill presses is identical in principle with that of sand, periods of aeration and treatment alternating. The minimum working strength is determined by the ability to precipitate the solutions. For a ten-day period the consumption of NaCN per ton of slime was: In treatment, 0.127; added for precipitation, 0.008; total, 0.135. The cyanide added for precipitation is usually added with the feed of zinc dust. An excessive amount of zinc dust is also necessary to insure clean precipitation of these solutions, entailing further expense in refining as well as in the first cost of zinc. These additional costs consume about 25 per cent of the profit of reducing cyanide consumption.

The tonnage of slime treated is measured by the "flow gravity" system, which the author elaborates as follows:

Procedure.—Valves on the two "sludge tanks" receiving the incoming stream of pulp are closed. The depth of slime in each tank and the time are noted. The stream of pulp is now diverted to tank *A*, the discharge valve from which is closed, the presses being served with pulp delivered from tank *B*. When tank *A* is filled, the time and volume are noted, the valve from *B* is closed, the pulp turned to tank *B* and the discharge valve from tank *A* is opened. These alterations continue throughout the period assigned for measuring. Changing, which is at intervals of about thirty-five minutes, is not instantaneous, but the actual measurements cover 90 per cent of the total time, sufficient to insure a correct average rate.

At half-hourly intervals the stream of pulp is cut by a mechanical sampler, a 5-gal. bucket being filled and the weight of pulp determined. These determinations

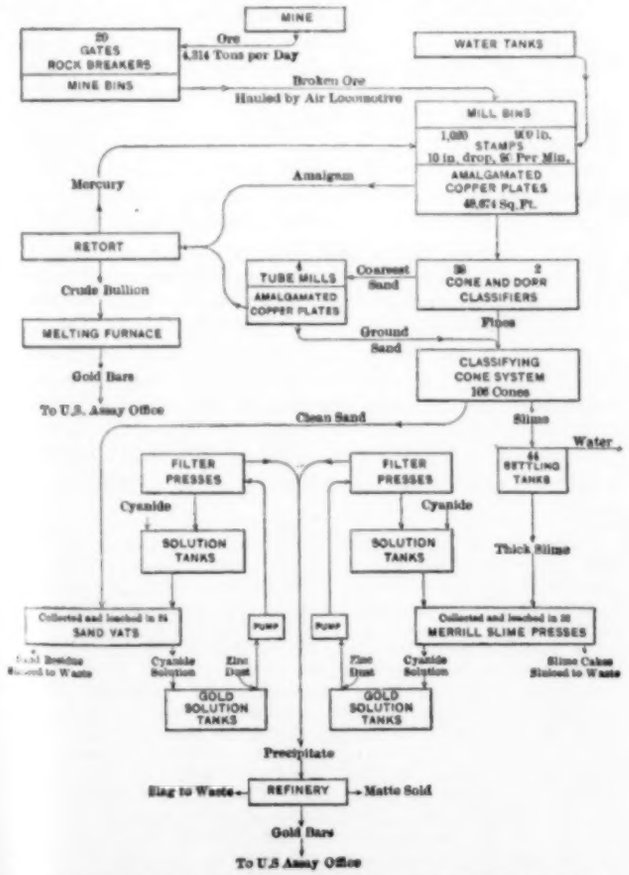


FIG. 1—FLOW SHEET SHOWING ORE TREATMENT AT HOMESTAKE MINE

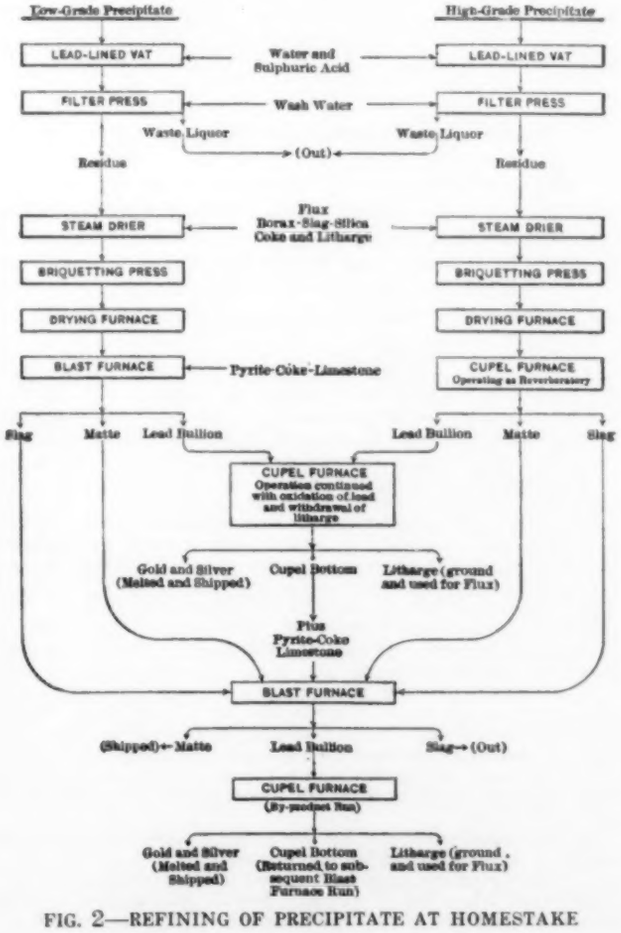


FIG. 2—REFINING OF PRECIPITATE AT HOMESTAKE

are averaged. A specific gravity determination is made on the average sample of slime.

Estimate of tonnage treated between noon of April 8, 1915, and noon on following day:

	Feet	Cubic Feet
North Sludge Tank:		
Total depth pulp to tank	132.667	
Deduct, lime water	1.078	
Balance, slime pulp	131.589	
131.589×518.85 (cu. ft. per foot of depth)		68,274.95
South Sludge Tank:		
Total depth pulp to tank	125.334	
Deduct, lime water	1.003	
Balance, slime pulp	124.331	
124.331×514.42		63,958.35
Total cubic feet for 22.05 measured hours		132,233.30
Estimated pulp for 24 hr		143,927.28
Correction for excess pulp in tanks at end of test		3,590
Cubic feet of pulp run to presses during test		140,337+

During the test, 39 determinations were made of the weight of 5 gal. of pulp. The average of these determinations gave the following data:

Percentage of solids in pulp	33.68
Weight of 1 cu. ft. of pulp	80.60 lb.
Solids in 1 cu. ft. of pulp	27.146 lb.

Total solids to presses during test = 140,337×27.146 = 3,809,600 lb. = 1,904.8 tons, which was divided among 73 presses, making the average charge of 26.09 tons.

SLIME PLANT OPERATING COSTS FOR 1914

	Operating Labor	Other Labor	Power	Chemicals	Miscellaneous	Total
Superintendence	$0.0093	.....	.....	.....	.....	$0.0093
Assaying	0.0021	.....	.....	$0.0005	$0.0005	0.0031
Thickening	0.0033	.....	.....	.....	0.0001	0.0034
Neutralization	0.0055	.....	$0.0004	0.0144	.....	0.0203
Treatment	0.0342	$0.0027	0.0152	0.0433	0.0119	0.1073
Precipitating and pumping solutions	0.0039	0.0006	0.0016	0.0096	0.0008	0.0165
Heating	0.0004	.....	.....	.....	0.0013	0.0017
Refining	0.0026	.....	.....	.....	0.0040	0.0066
Miscellanies	0.0057	0.0009	0.0012	.....	0.0010	0.0088
Repairs	.....	0.0042	.....	.....	0.0026	0.0068
Total operating	0.0670	0.0084	0.0184	0.0678	0.0222	0.1838

aMinor repairs are carried as Miscellanies; heavy items of repairs, necessitating the presence of carpenter's crew, are included here. Press cloths cost $0.0100 per ton of slime treated.

Unit consumptions per ton of slime treated: Sodium cyanide, 0.161 lb.; zinc dust, 0.118 lb.; lime, 3.48 lb.; hydrochloric acid, 0.393 lb., costing $0.0093 per ton treated; power, 1.15 kw.-hr.

Copper

Hydro-Electric Treatment of Copper Ores.—A research by ROBERT R. GOODRICH on the treatment of an Arizona porphyry ore by a process including the following steps: Oxidizing roast, leaching with sulphuric acid and electrolytic precipitation of the dissolved metal is given in a paper read at the San Francisco meeting of the American Institute of Mining Engineers. The author gives the following epitome of his rather extensive paper:

1. The most suitable temperature for roasting the Arizona porphyry copper ore, containing sulphides, in order to render it amenable to acid leaching methods, is between 600 deg. C. and 725 deg. C. The more finely ground the material the shorter the time required for the roasting so as to produce the maximum amount of soluble copper: materials which will pass through a 20-mesh screen and remain on 80 mesh require about 2 hr. roasting at 600 deg. C. to 725 deg. C.; and when ground to pass through an 80-mesh screen the time required is about 1¼ hr. If the roasting is concluded at temperatures above 800 deg. C., the oxidized copper is converted into a compound which is insoluble in dilute sulphuric acid. The longer the roasting is conducted above 800 deg. C., the greater the amount of insoluble copper produced.

2. A heated solution is necessary to leach efficiently the copper from the roasted material. A 10 per cent H_2SO_4 solution at 100 deg. C. leached out, in from 3 to 6 hr., all the copper from all roasted materials (through 40 on 80 mesh, through 80 mesh, whole through 20 mesh), except material through 20 on 40 mesh, in which case the extraction was not so high.

3. The nature of the anode is an important factor in securing depolarization by sulphur dioxide gas.

4. Depolarization with consequent saving in power is accomplished when using sulphur dioxide gas with a carbon anode, while there is no depolarization with a lead anode.

5. The depolarization by sulphur dioxide gas, even with carbon anodes, does not reach the theoretical amount, being between 45 and 65 per cent.

6. The amount of depolarization effected by sulphur dioxide gas when used with carbon anodes varies with the current density, being a maximum at low current density.

7. The method of introducing the sulphur dioxide gas into the cell is unimportant. All that is necessary is that it be introduced in some way, and in such quantity that the electrolyte is saturated with the gas, so that there is some escaping by bubbling at the surface.

8. A smoother deposit of copper forms when using sulphur dioxide gas as a depolarizer than when not using it.

9. In the electrolysis of an acid solution of copper sulphate, when sulphur dioxide is not supplied to the cell and when one is endeavoring to carry electrolysis to the point of complete extraction, a soft spongy deposit begins to form on the cathode before the complete extraction of the copper is effected. There is also a considerable rise in polarization when the copper contents of the electrolyte becomes low.

10. In the electrolysis of an acid solution of copper sulphate, when sulphur dioxide is supplied to the cell, the copper contents of the electrolyte may be reduced to a very small trace with the formation of a good, firm cathode, without rise in polarization toward the end. Current density and energy efficiency remain high to the end. It is only when prolonging the operation beyond the time when but a small trace of copper remains that sulphide of copper forms as a thin coating on the cathode.

11. Lead anodes do not peroxidize or deteriorate appreciably when used with or without the introduction of sulphur dioxide into the electrolyte.

12. A novel idea—step arrangement of process—makes feasible the depositing of copper continuously, while the copper contents of said electrolyte in the respective steps remains constant. A plant composed of several steps of such cells may be operated so that a liquor strong in copper flows to the plant continuously, and the liquor which outflows from the plant is depleted of its copper.

13. The circulation of the electrolyte by the step arrangement increases the current efficiency. Such rapid circulation is not possible in plants as ordinarily arranged.

Lead

High-Lime Slags in Lead Smelting.—A discussion by S. E. BRETHERTON of the advantages of using more lime and less iron in the smelting of lead ores for the purpose of neutralizing silica was given in a paper before the American Institute of Mining Engineers at San Francisco. The author gives Anton Eilers credit for introducing this departure in 1878-79. The use of lime was less expensive and enabled the metallurgist to make a more silicious slag of lighter specific gravity which contributed to a better separation of metal and matte. It also prevented the formation of "sows" in the lead crucible. When smelting arsenical ores, the use of high-lime slags resulted in the production of less speiss. With the smelting of sulphide ores in Colorado and Utah, matte became a by-product and arsenic gave less trouble. It was generally supposed that the arsenic was taken up in the matte and finally lost in its treatment. The author believes that this was true to a certain extent, but gives the following personal experience to show the effect of high-lime slags in eliminating arsenic.

"The ore to be smelted contained an average of about 3½ per cent lead, 6½ per cent iron, 2½ per cent manganese, 7 per cent zinc, 21 per cent lime, 11.7 per cent magnesia, 8½ per cent silica, 1 per cent alumina, 3 per cent arsenic, and only a trace of sulphur, together with a very small amount of ore, which we called our lead ore, from another mine averaging 11½ per cent lead, 20 per cent iron, 4 per cent zinc, 3 per cent lime, no manganese, no magnesia, 30 per cent silica, and only a trace of either arsenic or sulphur. From this it can be seen that there was more than enough arsenic to make a large proportion of speiss (especially as we smelted regularly considerable speiss containing gold and silver from some old slag dumps in the neighborhood), and no sulphur to make a matte to absorb it. At the same time, the bulk of the ore being so low in iron and manganese and high in lime and magnesia, I was compelled to make a slag very rich in lime and magnesia. The result was that we produced no speiss or matte, excepting once for a few hours when we fed in some sulphide ore to see what the results would be.

"The only detail in our practice which differed from the ordinary method of smelting was to cupel our bullion for shipment until it was rich in gold and silver, so as to use the lead as litharge over again in the charge. The fact that we were able to get rid of the arsenic in the ore and speiss from old slag dumps and make a comparatively clean slag led me to believe that the high percentage of lime base in the charge and the lack of iron with which the arsenic could combine, resulted in the volatilization of the arsenic, this action no doubt being assisted by the oxidizing influence of the litharge used. While our gold and silver losses were satisfactorily low, our lead losses were very high, which was to be expected when using the lead over and over again in such an oxidized mixture and keeping the coke consumption as low as possible. Coke was the only reducing agent used."

Fuels

Oil Fuel for Heating, Melting and Heat Treatment of Metals.—A paper by W. N. BEST describing some of the applications of oil-firing in boilers for power plants and in commercial furnaces of special design for melting metals and heat treatment of metals, was presented at the San Francisco meeting of the American Institute of Mining Engineers. The paper contains a number of designs of furnaces and calls attention to the necessity for avoiding rule-of-thumb methods in applying oil combustion.

"There has been a greater development in furnace construction during the past four years than in all the world's previous history. It requires 2009 cu. ft. of air to furnish the oxygen requisite for the combustion of 1 gal. of oil. Only about 20 per cent of this air is oxygen, while the other 80 per cent is nitrogen and other gases which unfortunately must be heated up to the same temperature as the furnace, but, for economy's sake, must be expelled as quickly as possible. It is therefore necessary that the furnace construction be such that the consumed and inert gases will be expelled at once. The combustion chamber should be so located and of such form and proportions as to insure perfect reverberation of the heat, while aiding in the quick expulsion of the gases. Only one burner should be used on any billet-heating furnace, no matter whether the charging space be 12 by 18 in. or 8 by 24 ft. in size. For a regenerative melting furnace two burners are necessary; but of course only one burner is in operation at any one time. In all other melting furnaces, whether the bath be 2 ft. square or 20 by 140 ft., whether the product requires an oxidizing or a reducing flame continuously or alternately, only one burner should be used. Additional burners make the operation of the furnace too complex. While the operator may strive to run them all alike, some will be giving an oxidizing and others a reducing flame, thereby impairing the efficiency of the furnace.

"In the designing of furnaces the question is not how many burners can be used, but how few will do the work. A poorly constructed furnace will ruin the efficiency of the best oil burner ever made, while a poor burner will ruin the efficiency of the finest furnace ever designed. It is as impossible to cover a flat furnace bottom or charging space with a round flame as it is to fill a square hole with a round plug. To obtain the highest efficiency and strictest economy it is necessary to have a good furnace, scientifically designed and constructed, as well as a superior type of oil burner."

Viscosimeters

BY R. F. MACMICHAEL

Viscosimeters are instruments for measuring the viscosity of fluids. They operate on two general principles.

First.—The *time* required to produce a definite relative movement of the fluid particles under a given force.

Second.—The *force* required to produce a definite relative movement of the fluid particles in a given time.

Familiar examples of the application of the first principles are:

a.—Long capillary tube, used by scientists.

b.—Short-tube commercial instruments, as Saybolt, Engler and Redwood.

c.—Falling bodies within the fluid, as Arnold, Ladenburg and Flowers.

d.—Rising bubble.

e.—Retarded surface, as Doolittle and Stormer.

In each of these instruments the time required for a definite movement of the fluid particles to take place is noted.

The acting force in each case, except that of Doolittle, is gravity. This may be the weight of the fluid itself, or the weight of a foreign body acting within or upon the fluid, or buoyancy of an air bubble. In the case of Doolittle, energy is stored up in a steel spring, and allowed to expand itself in rotating a disk.

In well-designed instruments of this class, the control of the acting force is almost absolute. However, the time required to make a test is frequently a drawback in the use of the instrument, and the difficulties of maintaining an exact temperature during the test are often very serious.

The fluid must usually be strained before testing. On very viscous fluids, this necessitates heating. Small particles of foreign matter within the instrument may

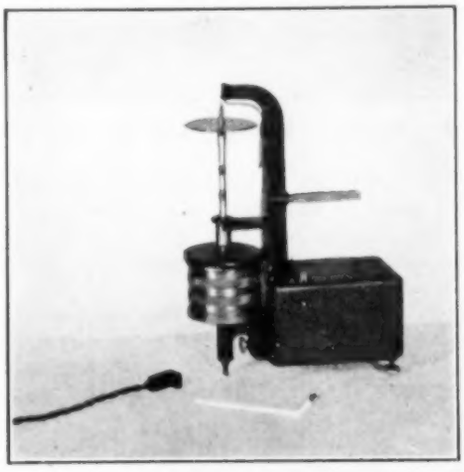


FIG. 1—VISCOSIMETER ASSEMBLED

interfere with proper action, and at times will introduce very large errors.

It is only rarely that colloidal or glue-like substances, or suspensions of finely divided solids, such as clay slips, can be handled successfully in these instruments.

Results are usually expressed in seconds of time. Even in the simplest forms of instruments, elaborate and involved calculations are required to reduce the readings to scientific units, while most of the instruments noted above are not susceptible even to such calculations. In the latter case the results are expressed in an arbitrary manner in empirical units.

The personal equation is large, and considerable care and skill are required if accurate results are to be obtained.

Viscosimeters of each of the above types have been before the public for many years. Up to the present it has not been found possible to combine in any one instrument based on the first principle all of the essential features required in a viscosimeter for general scientific and commercial use.

The most prominent examples of instruments based on the *second* principle are those of Couette, Clark and MacMichael.

In each of these instruments a cylinder or disk is suspended in a cup of fluid, and either the disk or the cup is revolved, and the torsional force noted.

Couette's experiments were conducted at an early date, and though the principles involved were sound, mechanical difficulties were encountered which proved

quite insurmountable at the time of its development.

In the more recent Clark machine, the tangential force applied to the rotating member is measured. This instrument under proper conditions gives excellent results, but the construction introduces mechanical complications which render it unsuitable for general use.

In the MacMichael viscosimeter, the force exerted by the rotation of the fluid itself on the stationary

FIG. 2—CUP AND PLUNGER REMOVED FOR CLEANING

member is measured. This force is equal and opposite to that applied to the rotating member.

The construction is simple and durable. Operation is rapid and accurate, and results are expressed directly in scientific units.

The photograph in Fig. 1 shows the machine assembled and ready for a test. A disk is suspended in the cup of fluid by a torsion wire about ten inches long, running down through the stem of the plunger, and fastened near the bottom.

The head of the torsion wire is triangular, and is held between two grooved pins at the top of the standard. The cup and plunger may be removed and replaced without manipulating any catches or fastenings.

Fig. 2 shows the cup and plunger removed for cleaning. All surfaces are smooth and rounded and may be cleaned with the greatest ease.

The cup is oil jacketed, being formed of two pieces of heavy spun brass. Within the oil jacket is immersed an electric heating coil. This coil draws current from the same line as the motor, only one connection being necessary.

The fluid to be tested is heated in place, no other heating device being required. The operation is very rapid. Stirring is effected by a slight vertical movement of the plunger.

For low-temperature work, the fluid and the adjacent parts are chilled in an ice bath or brine solution.

A bent thermometer inserted through an opening in the cover indicates the temperature, the bulb being immersed in the fluid. The temperature during test may be controlled within a small fraction of 1 deg. Fahr.

The graduated dial at the top of the plunger is secured to the stem by a friction disk, permitting the adjustment of the zero mark to its proper location. The fine adjustment is effected by means of the steel wire pointer at the head of the standard.

The same figure shows the dash pot on the stem of the plunger. This device is frictionless and automatic in action, and requires no attention from the operator. Its function is to check incipient vibrations and to permit quicker readings by damping the action.

In Fig. 3 the standard and hood are thrown back, showing the driving mechanism. The speed control is of the familiar phonograph type and gives excellent results. The motor is specially wound for this service and is furnished either for alternating current or direct current, for use on ordinary lighting circuits. Variations in voltage do not affect the accuracy of the determination.

In operation, the cup is filled to the mark on the side with the fluid to be tested. This requires about 100 c.c. The cover is put on and the thermometer inserted.

By means of the heating coils the temperature is raised to nearly the desired point. As expansion of the fluid will probably have taken place, the excess fluid is removed by means of a pipette furnished with the machine. This automatically fixes the proper level without further attention from the operator.

The temperature is brought exactly to the desired point, the thermometer removed and the motor started. Within a few seconds the dial will have come to rest, and will remain steadily at one point. The deflection noted is the viscosity of the fluid.

This entire operation is very rapid, so that the drop in temperature on ordinary work is entirely negligible.

For extreme accuracy, the temperature may be raised slightly above the desired point, and an allowance made for the drop up to the moment of reading. This will seldom be found necessary in actual practice.

The readings are in degrees of angular deflection, 300 deg. to the circle, designated as deg. M. The practical working unit is 1/1000 of the absolute unit.

FIG. 3—STANDARD AND HOOD THROWN BACK TO SHOW DRIVING MECHANISM

As water at 20 deg. C. or 68 deg. Fahr has exactly 1/100 of the absolute unit of viscosity, water at this temperature reads 10 deg. M.

Thus by shifting the decimal point practical units, absolute units, and specific viscosity may be obtained at one reading. Readings are taken directly from the dial, no intermediate calculations being required.

Gold plated torsion wires are supplied. These wires are of the very highest grade steel. They are extremely strong and their elastic properties are not affected by use. The heads are solid and will not break.

Torsion wires ordinarily give water as 10 deg. M and may be used up to 500 deg. M. This covers the range of most liquids ordinarily to be tested.

For extremely thin and extremely thick liquids, lighter and heavier wires giving readings for water of 100 deg. and 1 deg. respectively, are supplied. This covers every range of viscosity up to about 5000 deg. M, or 500 times that of water.

Calibration of the instrument is effected by testing with a standard fluid of known viscosity. Sugar syrup is used for this purpose. Water may be used for calibrating, but this is not advisable as it is too thin for the best results.

Should the reading of the dial, on test, be found to vary slightly from the correct value, the speed of rotation of the cup is altered by means of the speed control screw at the lower front of the machine.

The deflection of the dial will vary directly as the speed, other factors being constant, and the correct indication may be obtained. When calibrated accurately for one value, the readings will be correct for any other value.

The accuracy of the instrument under ordinary working conditions should be well within an error of ½ per cent above or below the true value. For extremely accurate work, extra precautions should insure results within a small fraction of this error.

As the time required for a reading is extremely short, determinations may be made on suspensions, such as clay slips, which settle rapidly.

Thus, the determination of the plasticity of clay by the MacMichael method is readily made by the use of this instrument. The instrument was originally developed for this particular purpose.

Colloidal solutions may also be handled successfully. This includes glues, gums, starch solutions, gelatine, and other similar materials. Likewise, the viscosity of complicated mixtures such as catsup, or other food materials or chemical substances, may be readily determined. Straining is unnecessary as small particles of foreign material do not in any way affect the accuracy of the determination.

The instrument, with its thermometer and pipette, is complete in itself. No stop watch is required, and no gas burners or other heating device, and no dippers, strainers, graduates, flasks or other parts except as noted.

Skilled labor is not required in its use, as any careful operator may learn to use it in a very short time. The personal equation is small.

The entire machine is built in the most substantial and durable manner, and is guaranteed by the builder.

It is believed that this instrument offers an accurate, rapid, convenient and thoroughly satisfactory means for determining the viscosity of fluids.

Seattle, Wash.

A New Vacuum Pump

Many processes, such as the various vacuum filtration systems now in general use in the mining and metallurgical field, require a vacuum. The modern powerhouse equipment invariably includes a condenser plant, the efficiency of which depends upon the degree of vacuum within the condensing apparatus.

For maintaining this vacuum and for general service in other lines where a high degree of vacuum is desired, the Ingersoll-Rand Company, 11 Broadway, New York, has recently introduced a complete line of steam and power-driven, duplex-type, "Imperial" vacuum pumps.

In general design these machines follow that of the "Imperial" air compressors, a type with which engineers and power plant operators are long familiar.

The vacuum cylinders, as will be seen from the sectional illustration, are different from those ordinarily met with. The intake valves are of the Corliss type, so placed in the cylinder head that the clearance is exceptionally low. This is a desirable feature in that the air trapped in the clearance spaces at discharge pressure will not reach such a volume, upon being expanded to intake pressure, as to greatly limit the pressure reduction which may be obtained. The action of the valve is positive and quick and, its action being independent of the cylinder and intake pressures, the pressures within and without the cylinder are as nearly equal as possible.

The intake ports are larger and direct, which together with the water jacketing of the valve tends to cool the intake gases.

The discharge valves, which are of the "direct-lift" poppet type, are placed in the bottom of the cylinder heads so that any entrained moisture or water is imme-

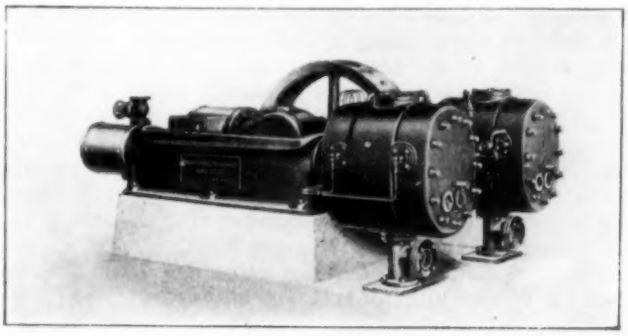


FIG. 1—STEAM-DRIVEN VACUUM PUMP

diately discharged, a feature that makes for safety in handling moist or even saturated vapor. Clearance at the point of discharge has been reduced by making the valve partially fill the port in the cylinder head. These discharge passages are also water jacketed.

The cylinders are said by the manufacturer to meet fully the requirements of satisfactory and efficient operation. The air passages are unobstructed. Tie bolts pass from head to head and hold cylinder and heads tightly assembled. Both cylinder and heads are completely water jacketed, which is said to be an essential feature in the design of vacuum pumps, as the high

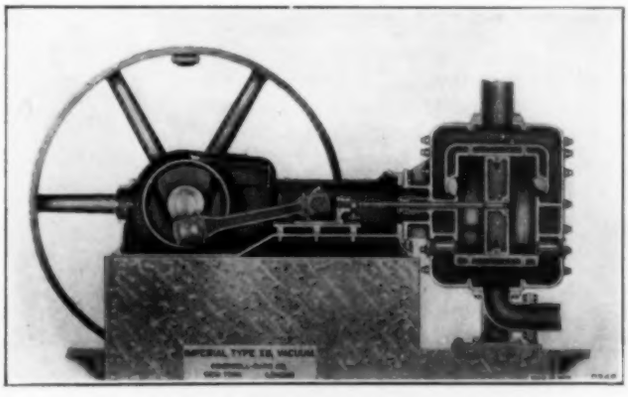


FIG. 2—SECTION OF VACUUM PUMP

ratios of compression tend to create high discharge pressures unless the heat is removed as generated.

The unusually low clearance in "Imperial" vacuum pumps has been obtained, not by dangerously close piston clearance, but by the correct design of the valves and valve ports.

Owing to the extremely low clearance, the complete water jacketing, the use of mechanically operated Corliss inlet valves and other refinements of design the manufacturer guarantees the easy maintenance of a vacuum of within ½ in. of barometer.

The running gear, that is, the main frame with its inclosed reciprocating parts, the crank shaft, connecting rod, crosshead, valve gear and wheel on both belt

and steam-driven machines are of the same design as the "Imperial" air compressor. Lubrication is by the bath system, providing automatic flood lubrication, yet retaining by the removal of covers from the casing, all the points of accessibility of the open type of machine. When operating the flywheel is practically the only visible moving part, yet the entire mechanism is readily accessible while in motion.

The Imperial vacuum pump occupies less floor space than similar capacity machines of the straight-line type, due to its duplex construction and to the fact that its speed of operation is higher.

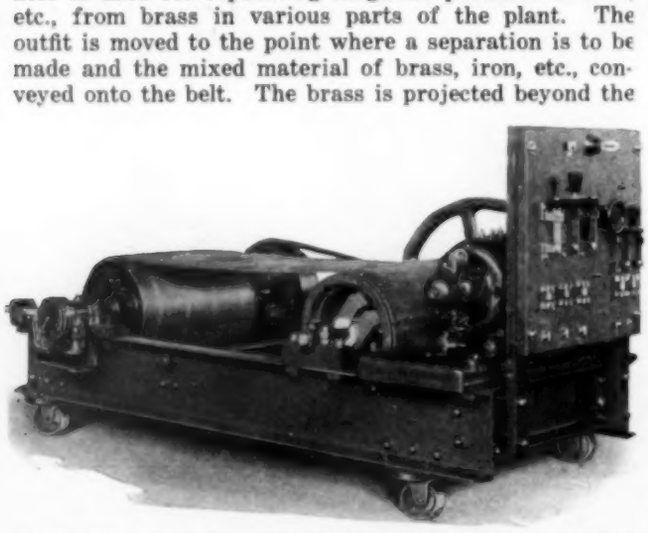
In reality a duplex machine such as this is two identical units of like capacity united by one common frame with cranks at 90 degrees. This makes it possible, should requirements fall temporarily below that for which the equipment was originally installed, to remove one connecting rod and the operation of one-half the machine discontinued, while the other half operates at its rated speed and hence its utmost efficiency, displacing, however, one-half the vapor the entire machine is capable of handling.

These machines are built in capacities from 798 to 7048 cu. ft. per minute, both for atmospheric and low-pressure (5 lb.) discharge.

The manufacturer claims for these vacuum pumps that they operate practically independent of attention and are thoroughly efficient and economical machines for maintaining a high vacuum.

New Portable Magnetic Separator Outfit

The accompanying illustration shows an interesting portable magnetic separating outfit built for the Graphite Lubrication Co., of Boundbrook, N. J., by the Cutler-Hammer Clutch Co., of Milwaukee. The separator is used for separating magnetic particles of iron, etc., from brass in various parts of the plant. The outfit is moved to the point where a separation is to be made and the mixed material of brass, iron, etc., conveyed onto the belt. The brass is projected beyond the



PORTABLE MAGNETIC SEPARATOR OUTFIT—THE MAGNETIC PULLEY IS SHOWN AT THE LEFT

pulley freed from magnetic pieces since the latter stick to the belt in passing over the magnetized pulley and are dropped below where the belt leaves the pulley.

This installation is particularly intresting, as in this plant only alternating current was available. The direct current for the magnetic pulley is furnished by a small 110-volt generator which is driven by the same alternating-current induction motor that drives the pulley. The small panel mounted at one end of the frame carries the three-pole motor knife switch and fuses, the double-pole generator knife switch and fuses, back-of-board type dynamo field regulator and pilot lamp.

Welding Defective Cores in Paper Mill

The St. Croix Paper Company of Woodland, Me., was formerly throwing all broken and defective paper cores on the scrap pile. Much of this material was sold as junk at the best prevailing market prices. Many carloads of broken and defective cores had been disposed of in this manner before it was discovered that all of them could have been made as good as new by employing oxy-acetylene welding.

By using the Prest-O-Lite process of oxy-acetylene welding, broken cores similar to those shown in the illustration are now repaired in nine minutes. No filling material is used as a method has been found for handling the welding operation so that sufficient strength can be obtained with the material flowed into the weld from the pipe itself. Occasionally, however, a small quantity of filler rod has to be added to insure a joint that will be as strong as the rest of the core itself.

The two sections of pipe are prepared by simply cutting off in a machine with the regular cutting-off tool. The ends of the pipe are not beveled as the extra metal is needed where filling rod is not added.

The cores are steel tubes 3 in. in diameter and average about 50 in. in length. During the welding operation they are slipped over an iron arbor of the same

BROKEN CORES IN PAPER MILL WELDED BY OXY-ACETYLENE PROCESS

diameter as the shaft on which the roll is designed to run to insure perfect alignment with the longitudinal center.

As these cores accumulate very rapidly in the enormous production of the St. Croix Paper Company, it is stated that enough material, heretofore scrapped, is now on hand to furnish several years' supply of new cores without making it necessary to draw on any new material at all.

Tests of welded paper cores indicate that the reclamation process does not affect the original strength in the least—the welded portions stand the punishment incident to rough handling during continual shipping, although frequently the *original* metal in the tube is broken.

Former methods at repairing these damaged cores were very unsatisfactory. One method was to make a hammered weld in a blacksmith forge, first preparing the ends of the rolls by beveling one piece on the inside and the other on the outside so that they fit together snugly, making what was practically a lap weld. This method was exceedingly troublesome.

It is estimated that 250 lb. of coal was used daily in maintaining the fire for the blacksmith's welding operation and only a small number of cores could be repaired in a day as compared with the more economical method of welding by the oxy-acetylene process.

In view of the low cost of the oxy-acetylene welding equipment required and the greater speed with which the repair of broken cores is accomplished, the saving effected by the St. Croix Paper Company is considerable.

Personal

Mr. **Edward L. Brayton**, president of the Pelton Water Wheel Co., San Francisco, Cal., has recently spent some time in New York City.

Mr. **Russel A. Cowles** has resigned his position as a vice-president of the American Brass Company and has become associated with the Buffalo Copper & Brass Rolling Mill, Buffalo, N. Y., and has also recently been elected president of the Metals Trading Corporation.

Mr. **J. V. N. Dorr** was recently in New York, having spent the summer in San Francisco and on the Pacific Coast.

Dr. **James Douglas** of New York has donated $150,000 to McGill University, Montreal, for the erection of a students' residence. He has also been offered the position of Chancellor of Queens University, Kingston, Ont.

Mr. **L. V. Emanuel** has become associated with the River Smelting & Refining Co., Florence, Col.

Professor **W. S. Franklin** has resigned as professor of physics at Lehigh University and will make a tour of the universities of the South and West during the coming fall and winter; he offers to give, in connection with this trip, a number of theoretical and experimental lectures on some needed additions to the subject matter of theoretical mechanics; on wave motion and oscillatory motion; on electric waves; on some phenomena of fluid motion and the curved flight of a base ball, and on "Bill's School and Mine." Professor Franklin's desire is that payment be made for these lectures sufficient to cover the expenses of the trip. Among the lectures to be delivered is also that on some mechanical analogies in electricity and magnetism by which the brilliant author aroused so much enthusiasm at the Atlantic City meeting of the American Electrochemical Society last spring. Professor Franklin's address is care of Columbia University, New York City.

Mr. **Edward Hamilton**, formerly assistant general superintendent of the Duquesne Works of the Carnegie Steel Co., has been appointed general superintendent to succeed Homer D. Williams, who has been elected president.

Mr. **W. E. Hardy**, formerly connected with the Diamond Rubber Co. and the B. F. Goodrich Co., has lately been appointed sales manager of the Boston Belting Co., Boston, Mass.

Mr. **J. E. Johnson, Jr.**, has been elected chairman of the New York Section of the Mining and Metallurgical Society of America. Mr. A. H. Rogers has been re-elected vice-chairman and D. M. Liddell has been re-elected secretary-treasurer.

Mr. **Robert M. Keeney** has accepted a position with the Standard Chemical Co., Canonsburg, Pa., producers of radium.

Mr. **F. C. Newton** has resigned his position as superintendent of the American Smelting & Refining Co.'s plant at Maurer, N. J., to become vice-president and general manager of the Newton Manufacturing Co., Lowell, Mass.

Dr. **Joseph W. Richards**, on his way east from San Francisco, was the guest of the Lehigh Intermountain Alumni Association at luncheon on Sept. 27, at the University Club, Salt Lake City.

Mr. **Charles Sagert** has been made superintendent of the open-hearth steel plant of the Brier Hill Steel Co., Youngstown, Ohio, succeeding Edward Bailey, who has become connected with the Algoma Steel Co., at Sault Ste. Marie, Ontario.

Mr. **H. B. Zeller** has resigned his position as assistant superintendent of the coke plant of the Republic Iron & Steel Co., Youngstown, Ohio, to become superintendent of the new by-product plant of the Toledo Furnace Co., Toledo, Ohio.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, National Union Building, Washington, D. C.

Electroplating

AQUEOUS BATH, APPARATUS

28,590, June 5, 1860, John Matthews, Jr., of New York, N. Y.

Relates to coating the interior of lead and other tubing employed in mineral water apparatus, with silver. The tube itself is employed as the decomposition cell and cathode, a rod or wire passing longitudinally through the tube serving as anode. The tube is straightened, placed in a vertical position, and its lower end closed with a suitable rubber closure through which the anode wire passes. The anode is maintained in a central position by disks of rubber placed at suitable intervals along its length, and is arranged to be moved at will, longitudinally, in order to insure a uniform deposit on the tube. Any suitable silver-plating solution may be used.

75,258, March 10, 1868, Marshall L. Forbes, of West Meriden, Conn., assignor to the Meriden Britannia Company, of same place.

Relates to electroplating spoons and other articles, and to giving them deposits of metal of increased thickness at such places as are subjected to the greatest wear. This is accomplished by immersing different parts of the article to be plated for different periods of time. Two forms of apparatus are shown, each of which supports the spoon at its center, and permits tilting to immerse a gradually increasing surface of the spoon, giving a thick deposit at one point, gradually fading off to the part of the surface where there is little or no wear. After the spoon has received the desired partial coatings, it is removed from the holder and completely immersed, giving it a complete coating. Or the operation may be reversed, by first applying the complete coating, then the desired partial coatings.

78,497, June 2, 1868, William H. Watrous, of Hartford, Conn.

Relates to a frame for holding spoons, forks, etc., to be electroplated. The frame consists of a two-part clamp, one part pivoted to the other, and provided with a pair of jaws each having a serrated, or notched, edge, the notches in each opposite to each other, and co-operating to form a slot in which is suspended the spoon, etc., to be electroplated. The two parts of the clamp may be adjusted to each other by a screw, to admit different sized articles for plating. The complete clamp may hold a dozen or more spoons. The clamp is protected from contact with the electrolyte by a suitable non-conducting coating. The clamp and spoons are immersed in the electrolyte to a depth sufficient to entirely coat the spoons.

84,243, Nov. 17, 1868, Justin P. Woodworth, of Brooklyn, N. Y.

Relates to electrodepositing metals upon articles such as spoons, which are subjected to unequal wear, and to producing a thicker deposit upon the parts which are subjected to increased wear. A supporting rack having a number of holes or openings large enough to hold the spoon or other article to be plated is suspended within the plating tank. A narrow slot from the edge

of the rack to each hole or opening permits the insertion of the spoon. On each side of the rack, and facing the front and back of the spoons are supported deflecting plates of insulating material which shield the parts of the spoon that are not subjected to wear, but exposing to deposit the parts which are subjected to wear. These deflecting plates or shields are adjusted so that a heavy deposit is produced where desired, and a thin deposit where there is little or no wear.

108,510, Oct. 18, 1870, Dubois D. Parmelee, of New York, N. Y.

Relates to electroplating the interior of lead and other pipes. The pipe is first straightened, and then placed on a support at an angle of 20 or more degrees from the horizontal. An anode of the metal to be deposited is provided with several disks of insulating material, having serrated edges, to keep it central in the tube. Means are provided to gradually draw the anode through the pipe, so as to deposit a uniform coating throughout its length. The pipe may also be rotated, or turned slightly, if desired. The lower end of the pipe is closed by a plug, and filled with a suitable plating solution.

114,191, April 25, 1871, Dubois D. Parmelee, of New York, N. Y.

Refers to his earlier patent 108,510, upon which the present invention is an improvement. In this patent, the pipe to be coated is supported vertically, and a plurality of separate anodes are connected together and hung therein, like a chain, the entire length of the pipe. A drum above the pipe serves to support the anode, and to move it longitudinally from time to time to give a uniform deposit. The bottom of the pipe is connected to a reservoir of electrolyte which is pumped into the pipe, and returned when the deposit is completed.

128,166, June 18, 1872, Dubois D. Parmelee, of New York, N. Y.

Refers to his prior patents 108,510 and 114,191. The present patent is for the pipe coated by the apparatus described in the prior patents. It further refers to minor changes in the apparatus and method of use, for which the patent should be consulted.

148,409, March 10, 1874, William H. Bush, of New Haven, Conn.

A frame or flat box is provided with a metal top, perforated with many holes, and a screen or perforated plate within. The sides of the box are either removed, giving an open frame, or are perforated with large holes, to freely admit access to the electrolyte. Screws, tacks, rivets, etc., are inserted in the holes in the metal top, the ends or points thereof engaging the screen within. The screws are then placed in the usual cleaning solutions, then in the electroplating bath, after which the heads of the screws are suitably burnished while still in the frame.

148,409, March 10, 1874, William H. Bush, of New Haven, Conn.

Relates to a mechanism which regulates the quantity of deposit to be placed on an article. The apparatus consists of a counterbalance to one end of which is suspended the article to be plated. The balance is adjusted so that any predetermined weight of metal may be deposited, after which the lever tilts and closes a circuit which rings a bell announcing that the operation is completed, and at the same time operates a magnet which opens the plating circuit.

148,667, dated March 7, 1874, Evans Casselberry, of St. Louis, Mo., and Nathan H. Edgerton, of Philadelphia, Pa.

Consists of a receptacle through the bottom of which pass conductors to which are attached bifurcated wires or plates of platinum or other unoxidizable material. Water or other liquids in the receptacle are decomposed into their elements at the electrodes, the oxygen and hydrogen liberated is collected and may be used for fuel or other purposes.

Book Reviews

American Fertilizer Handbook. Eighth Annual Edition, 1915. Price, $1.00. Philadelphia: Ware Bros. Company.

The current edition of this useful handbook contains more complete statistics of the fertilizer industry than have previous editions. The usual directories of fertilizer manufacturers, allied fertilizer trades, cottonseed oil mills, and packers and renderers are included with special articles and complete fertilizer materials statistics. Among the special articles are the following: German and other sources of potash supply, by Charles H. MacDowell; the sulphuric acid industry, by Andrew M. Fairlie; use of concrete in fertilizer plants, by H. W. Latta; dictionary of fertilizer materials, by Thomas Coulson Pinkerton, five years of cyanamid in America, by E. J. Pranke.

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Elektrochemie wasseriger Losungen.—(Electrochemistry of Aqueous Solutions), by Dr. Fritz Foerster, professor of the Institute of Technology of Dresden. Second enlarged and improved edition, 804 pages, with 186 illustrations. Price in paper cover, Marks 30; bound, Marks, 31.50 (retail price in New York, $10.50). Leipzig, 1915: Johann Ambrosius Barth.

This book is of the series of Applied Physical Chemistry Manuals edited by Prof. Dr. G. Bredig.

The first edition of Dr. Foerster's book appeared in 1905, and the decade's advance in both theoretical and applied electrochemistry has made the second edition necessary. While certain subjects are given more consideration than heretofore, the general plan is left unchanged. The author explains that it is, as before, a textbook which will point out primarily how the fundamental principles of electrochemistry are made useful by their application.

Conception of the broad field covered by the book may best be gained by listing its fifteen chapter titles, viz.: "Electrical Energy and Direct Current Electricity in General"; "The Law of Faraday and Its Practical Deductions"; "Theoretical Deductions from the Faraday Law, The Electrolytic Dissociation Theory"; "The Migration of Ions"; "Bath Voltage and Energy Efficiency"; "The Resistance of Electrolytes"; "Electrical Osmosis"; "The Production of Electrical Energy in Galvanic Elements"; General Theories of Electrolysis"; "Electrolytic Evolution of Hydrogen and Oxygen"; "Special Electrochemistry of Metals"; "Application of Electrochemistry to the Metals"; "Electrolytic Reduction"; "Special Electrochemistry of the Halogens"; "Electrolytic Oxidation." Author and subject indices are included, as well as references to all original articles.

The chapter on the application of electrochemistry to the metals is very comprehensive. It treats with all the important metals, giving greatest space to copper and its refining. The 150 pages devoted to the electrochemistry of the Halogens include both the theoretical and applied branches of this important division of the science.

Dr. Foerster is widely known by his contributions to scientific literature and his most recent edition is a reliable and useful standard reference book for all those interested in the applications of the electrochemistry of aqueous solutions.